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UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Marketing Service
Marketing Research Division

EXPERIMENTS ON DISTRIBUTING METHYL BROMIDE IN BULK GRAINS WITH AERATION SYSTEMS

by

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SUMMARY

Tests were conducted in upright storages such as concrete elevator tanks, and large and small steel tanks, and in flat storages, in the second of a series of studies to adapt grain aeration systems to the distribution of fumigants in bulk-stored grain. The distribution of methyl bromide in stored wheat, shelled corn, and sorghum grain was observed. With airflows ranging from 0.01 c.f.m./bu. to 0.25 c.f.m./bu., satisfactory distribution of the methyl bromide was obtained in these tests.

INTRODUCTION

This report is the second of a series in which will be presented the results of studies to adapt grain aeration systems to the distribution of fumigants. A Marketing Research Report giving a comprehensive description of grain aeration systems is being prepared. The first paper (Phillips)[2] demonstrated how aeration systems in ships' holds and in upright grain elevator tanks could be converted to permit recirculation of methyl bromide through the grain mass and obtain excellent distribution. Airflow rates in the range commonly used in aeration systems were sufficient for good distribution of the fumigant. By reconverting the system back to its original state, the fumigant could be removed from the grain within a few hours after the treatment was concluded.

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[1] This is one of the field stations of the Stored-Product Insects Section, Biological Sciences Branch, Marketing Research Division, Agricultural Marketing Service, U. S. Department of Agriculture.

[2] Phillips, G. L. Grain fumigation. Agri. Chem. X (1): 55-56, 117-121; X (2): 41-43, 133-135, Jan. Feb. 1955.

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In this report additional tests are discussed, covering studies in upright and flat storages, related to methods of distributing methyl bromide gas by adapting existing aeration systems.[3]

Other reports in the series will discuss the distribution of other fumigants, including HCN and liquid grain fumigant mixtures, by use of aeration systems.

Since a great many data are involved and different types of structures were used, the tests are divided into 7 series, and grouped under 4 headings according to type of structure.

TECHNIQUES

The principal means of evaluation used in these studies was determination of the gas concentrations by sampling at selected locations and at intervals during the fumigation. The concentration and distribution patterns thus revealed were coupled with observations on insect mortality where possible.

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[3] The tests reported herein were a cooperative study of the Stored-Product Insects Section, Agricultural Marketing Service, USDA; the Dow Chemical Company, and the Michigan Chemical Corporation. Acknowledgments are due many other organizations and persons for their assistance, or for the loan of facilities in which to conduct tests. These include Carl S. Bulger, W. Keith Whitney, L. M. Redlinger, and Delmar La Hue, of the Stored-Product Insects Section, for assistance in certain tests; Reed Hutchinson, David L. Calderwood, G. L. Kline, and Harry Converse, Handling and Facilities Research Section, Transportation and Facilities Branch, Marketing Research Division, Agricultural Marketing Service, for assistance in engineering phases; technical and field personnel of Dow Chemical Company and Michigan Chemical Corporation for arranging for the loan of facilities in which to conduct tests and for much assistance in conducting the tests; and to the following firms that made facilities available, and assisted in many ways to set up the tests: Lauhoff Grain Company, Danville, Ill.; Farmers Union Cooperative Elevator, Sterling, Kans.; Garden City Co-op Equity Exchange, Garden City, Kans.; Shawnee Milling Company, Shawnee, Okla.; Moore-Stauffer Company, Chickasha, Clinton, and Verden, Okla.; San-Ore Construction Company, McPherson, Kans.; Henderson Grain Company, Farwell, Tex.; Eckroat Seed and Feed Company, Oklahoma City, Okla.; Western Grain Supply Company, Everett's Switch, Tex.; Hereford Milling Company, Hereford, Tex.; Golden Grain Corporation, Taft, Tex.; and Gibbs Warehouse Company, Joshua, Tex.

Gas sampling and determination technique

In the previous tests in an elevator tank, plastic tubes for gas sampling were used at each desired level in the grain by stopping the grain flow at that point and lowering an operator into the tank to place the tube. In the tests reported herein dealing with elevator tanks, the tubes were formed into cables with one tube ending at each desired level. This cable was then attached to the cable of a temperature indicating device, if one was present, or to a ¼-inch steel cable installed for the purpose. The sampling cable was placed in position in the empty bin, and the bin was then filled. All tubes in the cable were numbered.

In steel tanks and flat storages, sampling probes were used. Each probe consisted of a 5-foot length of 1/8-inch pipe with a pointed tip in which four 1/16-inch holes had been drilled. Additional 5-foot sections of pipe with threaded connections were used to make up the desired length. Plastic tubing was connected to the upper end of the probe to lead to the location of the gas analyzer unit. Such probes were inserted into the grain mass as deep as 45 feet in some instances. The probes and tubes were arranged in a manifold for identification according to a predetermined pattern.

The gas samples were analyzed with a thermal conductivity gas analyzer adjusted to read direct in ounces of methyl bromide per 1,000 cubic feet. A manifold was devised to use with the sampling tubes, which cut the time of analysis per sampling line to one-third.

The same time intervals for periodic gas samplings were used in all tests. They were ½, 2, 4, 8, and 24 hours.

Insect samples

In most instances, natural insect infestations were observed to obtain data on the mortality produced. This was done before and at the end of the fumigation period. The grain was checked before fumigation to ascertain whether a natural infestation existed. This check consisted of probing the bulk grain and sifting the samples for insects. If the grain was found to be infested, the same area was again sampled at the end of the fumigation periods. It was not always possible to take samples and hold them for insect emergence, since the work was always away from the laboratory and extreme temperatures made it impossible to hold the samples until they could be returned to the laboratory.

When test insects were used, they were placed in either screen wire cages or plastic bottles with slits in the sides. Where the rice weevil was used as the test insect, both adult and immature stages were included. When the confused flour beetle was the test insect, only adults were used. The immature stages were held from 4 to 6 weeks for emergence. The adults were examined as soon as they were removed from the samples.

TESTS IN ELEVATOR TANKS

Series A

This series of tests was conducted in February and March 1955 in an elevator tank at Danville, Ill. Earlier tests had been made in the tank with shelled corn (Phillips).[4] This tank was 125 feet 3 inches high with an inside diameter of 24 feet and a 10-foot hopper bottom. It had a volume of 58,170 cubic feet and held approximately 48,000 bushels of shelled corn. It was fitted with a temporarily installed recirculation system, which consisted of a 12-inch perforated pipe extending across the hopper at about midpoint, a blower [5], and a return duct of 12-inch portable tubing extending up the outside wall and anchored to an inspection ladder. This recirculation system discharged the fumigant into the headspace. A damper was inserted near the discharge end so that the airflow rate could be varied. A complete description of this system is given in the first publication of this series.[4]

The purpose of the Series A tests was to determine the degree of distribution of methyl bromide in shelled corn when no circulation was used, and to repeat the earlier series in which gas distribution in shelled corn had been determined for three rates of airflow in the range usually used for grain aeration, with a load of wheat. In addition, two tests were made with loads of shelled corn using a higher dosage rate than previously. The temperature of the corn ranged from 52° to 68° F.

Six tests were made as follows:

A-1. Shelled corn; dosage rate of 0.86 lbs./1,000 cu. ft. released above the load, no circulation, exposure 24 hours; usual gas sampling pattern; at the 21-hour period additional sampling probes were sunk from the top level directly beneath the point of gas release, to each 1-foot depth up to 16 feet, and the gas concentrations were sampled.

A-2. Wheat; dosage rate of 0.86 lbs./1,000 cu. ft. recirculated for 55 minutes, blower speed 1,268 r.p.m. with damper half closed, airflow rate 0.01 c.f.m./bu.; exposure period 24 hours; usual gas sampling pattern; forced aeration for 2 hours.

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[4] Phillips, G. L. Grain fumigation. Agri. Chem. X (1): 55-56, 117-121; X (2): 41-43, 133-135, Jan. Feb. 1955.

[5] In this publication the term "blower" is used to designate a device to move air against static pressures above 1 lb./sq. in. and the term "fan" to designate ones operating at static pressures of less than 1 lb./sq. in., as defined by the American Society of Heating and Ventilating Engineers. In typical grain aeration systems, fans are generally used, but in tests reported herein both fans and blowers were used.

A-3. Same load as A-2; dosage rate 0.86 lbs./1,000 cu. ft., recirculated for 55 minutes, blower speed 1,268 r.p.m. with damper open, airflow rate 0.014 c.f.m./bu.; exposure period 24 hours; usual gas sampling pattern; forced aeration for 2 hours.

A-4. Same load as A-2; dosage rate 0.86 lbs./1,000 cu. ft., recirculated for 50 minutes, blower speed 1,600 r.p.m. with damper open, airflow rate 0.02 c.f.m./bu.; exposure period 24 hours; usual gas sampling pattern; forced aeration for 2 hours.

A-5. Shelled corn; dosage rate 2½ lbs./1,000 cu. ft., recirculated for 57 minutes, blower speed 1,268 r.p.m. with damper open, airflow rate 0.0175 c.f.m./bu.; exposure period 24 hours; usual gas sampling pattern; forced aeration for 3½ hours.

A-6. Shelled corn; dosage rate 2½ lbs./1,000 cu. ft., recirculated for 35 minutes, blower speed 1,268 r.p.m. with damper open, airflow rate 0.021 c.f.m./bu.; exposure period 24 hours, 2½ hours forced aeration.

No natural insect infestation was present in this grain.

The results are presented in tables 1 through 7. When no circulation was used, the penetration into shelled corn was practically nil. As shown in table 1, no gas was recovered at any sampling point from 15 to 115 feet deep up to the 19-hour period, but high concentrations were present in the headspace. At 21 hours (table 2) concentrations ranging from 3 to 12 oz./1,000 cu. ft. were found at each 1-foot level down to 16 feet deep.

The distribution in wheat was best with the airflow rate of 0.02 c.f.m./bu. (table 5), using the 8-hour period for comparison, and poorest with the flow rate of 0.01 c.f.m./bu. (table 3). It is assumed that a longer period of recirculation would have been beneficial with airflow rates in this range. In each instance the gas was removed satisfactorily by the 2-hour forced aeration.

The wheat provided more resistance to airflow, as expected, with the same blower and damper settings used in the earlier tests with shelled corn. The following airflow rates were measured:

Blower speed	Damper position	Commodity	c.f.m./bu.
1,268 r.p.m.	open	corn	0.0245
		wheat	0.014
1,268 r.p.m.	half-closed	corn	0.0201
		wheat	0.01
1,600 r.p.m.	open	corn	0.0317
		wheat	0.02

In the 2 loads of shelled corn where higher dosage rates were applied, the gas concentration was low in the wall position in the bottom half of the tank at 8 hours, but at 24 hours, the distribution was quite uniform, in test A-5 (table 6). In test A-6 (table 7), the concentrations were also low at the wall positions near the bottom, and they had not been improved at the 24-hour period. This would indicate the need for the pickup duct at the bottom of the tank to cover a larger area. The 3½-hour aeration period (table 6) removed practically all gas, but the 2½-hour period (table 7) was not sufficient and from 2 to 4 oz./1,000 cu. ft. had accumulated at the 24-hour period.

It was concluded from this series that distribution of methyl bromide with no circulation was very unsatisfactory; that airflow rates of 0.01 to 0.02 c.f.m./bu. would produce satisfactory distribution of methyl bromide in wheat in elevator tanks, provided the period of initial circulation was not too abbreviated; that there was so little difference between wheat and shelled corn in resistance to airflow that the same recirculation system could be used for either without change; and that the methyl bromide could be adequately removed following fumigation by aeration with the same range of airflow rates.

Table 1.--Distribution of methyl bromide in an elevator tank of shelled corn resulting from gravity penetration; dosage rate 0.86 lbs./1,000 cu. ft., test A-1

Sample location and number	Concentration per 1,000 cu. ft. after			
	1 hour	2 hours	3 hours	4 hours
	Ounces	Ounces	Ounces	Ounces
Headspace				
1. Above load	68	63	10	6
15 feet deep				
2. North wall	0	0	0	0
3. Center	0	0	0	0
4. South wall	0	0	0	0
35 feet deep				
5. North wall	0	0	0	0
6. Center	0	0	0	0
7. South wall	0	0	0	0
55 feet deep				
8. North wall	0	0	0	0
9. Center	0	0	0	0
10. South wall	0	0	0	0
75 feet deep				
11. North wall	0	0	0	0
12. Center	0	0	0	0
13. South wall	0	0	0	0
95 feet deep				
14. North wall	0	0	0	0
15. Center	0	0	0	0
16. South wall	0	0	0	0
115 feet deep				
17. North wall	0	0	0	0
18. Center	0	0	0	0
19. South wall	0	0	0	0
Bottom				
20. Hopper	0	0	0	0

Table 2.--Concentration of methyl bromide in the top 16 feet at the 21-hour period resulting from gravity penetration 1/, test A-1

Depth in shelled corn	Concentration per 1,000 cu. ft.	Depth in shelled corn	Concentration per 1,000 cu. ft.
Feet	Ounces	Feet	Ounces
Above load . .	6	9	8
2	7	10	7
3	8	11	7
4	9	12	7
5	10	13	7
6	11	14	7
7	12	16	3
8	12		

1/ This sampling area was directly below the point where gas was introduced and was not in the same verticle plane as the regular samples. This accounts for the 3-ounce concentration at 16 feet where no concentration was recorded at 15 feet in table 1. No sample was taken at the 15-foot depth in this test.

Table 3.--Distribution of methyl bromide in an elevator tank of wheat resulting from recirculation for 55 minutes with an airflow rate of 0.01 c.f.m./bu., and disappearance of gas resulting from forced aeration for 2 hours; dosage rate 0.86 lbs/1,000 cu. ft., test A-2

Sample location and number	Concentration per 1,000 cu. ft. during fumigation					Concentration per 1,000 cu. ft. during aeration				
	½ hour	2 hours	4 hours	8 hours	24 hours	½ hour	1 hour	2 hours	4 hours	24 hours
	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces
Headspace										
1. Above load	2	2	0	1	2	0	0	0	0	0
15 feet deep										
2. North wall	5	6	3	3	3	T	0	0	0	0
3. Center	2	2	2	0	2	0	0	0	0	0
4. East wall	4	5	4	4	3	1	0	0	0	0
35 feet deep										
5. North wall	7	8	7	6	4	2	0	0	0	0
6. Center	7	9	8	6	4	2	0	0	0	0
7. West wall	7	9	7	6	4	2	T	0	0	T
55 feet deep										
8. North wall	16	15	10	7	4	5	2	1	0	T
9. Center	20	19	13	9	6	5	2	1	0	1
10. East wall	3	5	3	1	1	0	0	0	2	0
75 feet deep										
11. North wall	13	14	10	8	6	5	2	1	0	1
12. Center	20	20	12	10	6	4	2	T	0	1
13. West wall	10	10	6	5	2	1	0	0	2	T
95 feet deep										
14. North wall	7	8	6	6	4	3	1	T	0	1
15. Center	17	16	10	7	2	5	T	1	0	1
16. East wall	18	15	9	8	3	5	4	2	0	1
115 feet deep										
17. North wall	4	4	1	2	1	5	4	2	0	0
18. Center	2	4	T	1	T	3	3	1	0	0
19. West wall	2	4	1	1	1	4	4	2	0	0
Bottom										
20. Hopper	0	2	0	T	0	0	0	0	0	0

Table 4.--Distribution of methyl bromide in an elevator tank of wheat resulting from recirculation for 55 minutes with an air-flow rate of 0.014 c.f.m./bu., and disappearance of gas resulting from forced aeration for 2 hours; dosage rate 0.86 lbs./1,000 cu. ft., test A-3

Sample location and number	Concentration per 1,000 cu. ft. during fumigation					Concentration per 1,000 cu. ft. during aeration				
	½ hour	2 hours	4 hours	8 hours	24 hours	½ hour	1 hour	2 hours	4 hours	20 hours
	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces
Headspace										
1. Above load	3	3	3	2	2	0	0	0	0	0
15 feet deep										
2. North wall	2	4	3	3	2	0	0	0	0	0
3. Center	2	4	3	2	2	0	0	0	0	0
4. East wall	3	4	3	2	2	0	0	0	0	T
35 feet deep										
5. North wall	4	6	3	3	3	0	0	0	0	T
6. Center	5	6	4	3	3	0	0	0	0	1
7. West wall	5	6	3	2	3	1	0	0	0	T
55 feet deep										
8. North wall	12	10	6	4	3	2	T	0	0	2
9. Center	13	12	6	5	4	2	T	0	0	2
10. East wall	4	4	3	2	2	0	0	0	0	0
75 feet deep										
11. North wall	12	10	7	6	5	T	0	0	0	2
12. Center	11	11	8	7	6	1	0	0	0	3
13. West wall	10	10	7	6	3	0	0	0	0	2
95 feet deep										
14. North wall	8	8	6	6	5	T	0	0	0	2
15. Center	18	16	12	10	7	3	1	0	T	3
16. East wall	18	16	12	10	7	3	1	0	T	3
115 feet deep										
17. North wall	5	6	5	4	4	T	0	0	0	2
18. Center	2	2	2	2	2	0	0	0	0	0
19. West wall	7	7	6	4	3	3	0	0	0	T
Bottom										
20. Hopper	0	T	1	1	2	0	0	0	0	0

Table 5.--Distribution of methyl bromide in an elevator tank of wheat resulting from recirculation for 50 minutes with an airflow rate of 0.02 c.f.m./bu., and disappearance of gas resulting from forced aeration for 2 hours; dosage rate 0.86 lbs./1,000 cu. ft., test A-4

Sample location and number	Concentration per 1,000 cu. ft. during fumigation					Concentration per 1,000 cu. ft. during aeration				
	½ hour	2 hours	4 hours	8 hours	24 hours	½ hour	1 hour	2 hours	4 hours	18 hours
	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces
Headspace										
1. Above load	13	10	10	7	4	0	0	0	0	0
15 feet deep										
2. North wall	9	6	6	4	3	0	0	0	0	T
3. Center	13	10	10	7	4	T	0	0	0	0
4. East wall	11	7	6	4	4	1	0	0	0	1
35 feet deep										
5. North wall	6	4	4	3	3	2	T	0	0	T
6. Center	6	4	4	3	3	2	T	0	0	T
7. West wall	5	3	3	2	3	2	T	0	0	0
55 feet deep										
8. North wall	7	4	4	3	3	3	1	0	0	T
9. Center	6	4	4	4	4	1	1	0	0	1
10. East wall	12	10	10	7	4	1	T	0	0	0
75 feet deep										
11. North wall	8	6	5	4	4	1	2	0	0	T
12. Center	5	4	4	4	4	1	1	0	0	T
13. West wall	11	10	8	6	4	1	0	0	0	0
95 feet deep										
14. North wall	6	5	4	4	3	1	T	0	0	T
15. Center	10	8	6	6	4	1	T	0	0	1
16. East wall	6	7	4	5	4	1	T	0	0	T
115 feet deep										
17. North wall	10	4	4	2	2	1	T	0	0	0
18. Center	3	3	1	2	2	1	T	0	0	T
19. West wall	12	10	8	6	2	1	T	0	0	0
Bottom										
20. Hopper	0	0	0	6	0	2	0	0	0	0

Table 6.--Distribution of methyl bromide in an elevator tank of shelled corn resulting from recirculation for 57 minutes with an airflow rate of 0.0175 c.f.m./bu., and disappearance of gas resulting from forced aeration for 3½ hours; dosage rate 2½ lbs./1,000 cu. ft., test A-5

Sample location and number	Concentration per 1,000 cu. ft. during fumigation					Concentration per 1,000 cu. ft. during aeration				
	½ hour	2 hours	4 hours	8 hours	24 hours	½ hour	1 hour	2 hours	4 hours	15 hours
	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces
Headspace										
1. Above load	22	22	18	12	6	0	0	0	0	0
15 feet deep										
2. North wall	19	18	15	8	7	0	0	0	0	0
3. Center	22	19	16	12	7	2	0	0	0	0
4. South wall	19	18	15	13	6	2	0	0	0	0
35 feet deep										
5. North wall	26	20	14	10	6	2	0	0	0	0
6. Center	19	19	15	10	5	4	0	0	0	0
7. South wall	20	19	16	11	5	4	0	0	0	0
55 feet deep										
8. North wall	25	20	16	10	7	4	3	2	0	0
9. Center	24	20	15	13	7	7	2	1	0	0
10. South wall	14	12	10	10	5	7	4	2	0	0
75 feet deep										
11. North wall	9	8	8	6	5	7	4	3	0	0
12. Center	26	24	18	14	7	8	2	2	0	0
13. South wall	19	16	13	10	6	8	3	2	0	0
95 feet deep										
14. North wall	12	12	8	6	5	7	4	2	0	0
15. Center	28	24	18	14	8	8	3	2	0	0
16. South wall	8	8	8	6	5	5	4	2	0	0
115 feet deep										
17. North wall	10	10	8	4	4	9	4	2	0	0
18. Center	18	26	20	14	8	7	2	2	0	0
19. South wall	10	8	8	7	8	6	3	2	0	0
Bottom										
20. Hopper	8	8	8	7	7	4	4	0	0	0

Table 7.--Distribution of methyl bromide in an elevator tank of shelled corn resulting from recirculation for 35 minutes with a airflow rate of 0.021 c.f.m./bu., and disappearance of gas resulting from forced aeration for 2½ hours; dosage rate 2½ lbs./1,000 cu. ft., test A-6

Sample location and number	Concentration per 1,000 cu. ft. during fumigation					Concentration per 1,000 cu. ft. during aeration				
	½ hour	2 hours	4 hours	8 hours	24 hours	½ hour	1 hour	2 hours	4 hours	24 hours
	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces
Headspace										
1. Above load	13	13	12	8	6	0	0	0	0	2
15 feet deep										
2. North wall	18	12	12	10	6	0	0	0	1	2
3. Center	12	11	11	7	6	0	0	0	0	2
4. South wall	12	12	8	8	5	0	0	0	0	2
35 feet deep										
5. North wall	20	13	12	10	7	4	0	0	1	3
6. Center	16	12	10	8	7	0	0	0	0	3
7. South wall	31	20	14	13	8	2	0	1	1	4
55 feet deep										
8. North wall	43	23	20	17	12	4	1	2	3	4
9. Center	30	16	18	11	10	0	0	0	1	4
10. South wall	44	26	20	16	10	4	2	3	2	4
75 feet deep										
11. North wall	20	14	12	11	8	6	2	2	3	4
12. Center	43	22	20	16	10	0	0	0	1	4
13. South wall	4	4	3	2	3	6	3	2	2	3
95 feet deep										
14. North wall	13	10	12	12	6	6	4	3	3	3
15. Center	54	24	16	16	12	4	3	0	1	4
16. South wall	6	5	5	3	3	2	4	2	1	4
115 feet deep										
17. North wall	4	0	2	2	0	3	4	3	1	2
18. Center	54	27	22	13	11	3	2	2	1	4
19. South wall	3	0	0	0	0	0	0	0	1	4
Bottom										
20. Hopper	12	8	8	8	0	0	0	0	2	2

Series B

Three tests were made in Kansas and Oklahoma in August, October, and December 1955, in wheat elevators equipped with aeration systems, in which the airflow direction was reversed and directed upwards through the grain from the floor ducts.

Test B-1 was made at an elevator in Sterling, Kans., in one of a series of silo-type concrete tanks 105 feet high and 26 feet in diameter with a volume of 54,000 cubic feet. The selected tank contained 47,000 bushels of wheat. The aeration system was one designed and installed by the Manhattan Field Office, Handling and Facilities Section, Agricultural Marketing Service, for a cooperative study with the operators on grain aeration. It consisted of a perforated, half-round, shell-type, closed-end aeration duct 36 inches wide, 18 inches high, and 12½ feet long situated in the center of the flat floor of the tank (fig. 1). A 15-inch pipe extended from the duct through the outside wall. The 1/12-inch perforations in the surface and ends of the aeration duct provided openings equivalent to 8.7 percent of its total surface area. A fan powered by a 7½-hp. motor operated at 1725 r.p.m. provided an airflow rate through the wheat of 0.04 c.f.m./bu. (fig. 2).

The gas sampling cables were attached to 4 temperature cables, 1 at the center and 1 about 5 feet from the wall in 3 of the 4 quadrants. Samples were taken from various depths as listed in table 8. Samples were taken from normal slope of wheat at the top, and at the north, center, and south sample locations at the 2-, 4-, and 6-foot intervals.

Test B-2 was made at Garden City, Kans., where another aeration system designed by the Manhattan Field Office, Handling and Facilities Section, was installed in a hopper-bottom tank. The tank was 101 feet high with a diameter of 18 feet. The aeration duct was a half-round, shell-type, closed-end duct 8 feet long, 36 inches wide, and 18 inches high, and was located at the top center of the sloping wall of the hopper, as shown in figure 3. It was connected to a fan duct on the outside by a 12-inch pipe. The perforations on the surfaces and ends of the aeration duct equalled 8.7 percent of its total surface area, the same as in the installation at Sterling, Kans. The fan was powered by a 3-hp. motor and produced an airflow rate of 0.049 c.f.m./bu. (figs. 4 and 5). The gas sampling cables were attached to temperature cables at locations in the center and about 3 feet from the wall in the 3 quadrants N, E, and S as shown in figure 3. Samples were taken at various depths as shown in table 9.

Methyl bromide was introduced into the duct system at the exhaust side of the fan and forced upward through the mass of wheat. The dosage was 2 lbs./1,000 cu. ft. for a 24-hour exposure. The fan was run for 18 minutes. This gave a good concentration of gas at the surface.

Test B-3 was made at an elevator in Shawnee, Okla. This elevator tank was 117 feet high with an inside diameter of 20 feet and a 7-foot conical hopper extending downward. The aeration duct system was a radial type (figs. 6, 7, and 8). The inside ducts were made from $3\frac{1}{2}$-inch tubing cut in 8'6" and 10'6" lengths. These had $\frac{1}{2}$-inch holes drilled on the bottom side, spaced so that theoretically an equal flow of air was induced in all parts of the wheat. These holes were covered by a V-strip of metal welded to the tube. The tubes were placed in a radial position around the conical hopper bottom, alternating the long and short tubes. Each tube had a tee which extended through a 4-inch opening in the hopper wall to connect to a ring-type duct extending around the outside of the hopper (fig. 9). Each tee was fitted with a rubber collar which was pressed down into the opening around the tee by the weight of the wheat, thus making an airtight seal around each outlet.

The ring duct was in two sections, each extending halfway around the hopper. These sections were connected to a 12-inch main duct by Y's. The main duct was then reduced to 10 inches and connected to a 10-inch metal collar which had been placed in position when the tank base was constructed, making an opening to the outside. The fan was connected to the outer end of the collar by a 12-inch flexible duct. The blower had a 14-inch intake and a 12 x 13-inch exhaust (fig. 10). The wheel was 29 inches in diameter and the housing was 40 inches. The blower was powered by a 20-hp. motor running at 1750 r.p.m. and the blower speed was 2200 r.p.m. The airflow rate was 0.023 c.f.m./bu.

Two gas sampling cables were located in the tank, one down the center, and one near the east wall. Samples were taken from various depths as listed in table 10.

The fumigant, odorized methyl bromide, was introduced into the duct system at the exhaust side of the blower and forced upward. The dosage rate was $2\frac{1}{4}$ lbs./1,000 cu. ft. because of heavy loss of gas from the system. The blower was run for 21 minutes and stopped.

The aeration systems were not modified in any way in these three tests except that the direction of the blower was reversed so that the flow was upward through the wheat. The methyl bromide was introduced in the duct system, and the fan operated with a top manhole open, until the gas reached the surface layer in an adequate concentration, at which time the blower was stopped and the manhole sealed. This method of distribution is termed the "forced distribution method," as opposed to the term "recirculation" used when a return duct is provided and the air gas mixture is actually recirculated through the mass several times.

The distribution of gas obtained in test B-1 is given in table 8. The gas was released over a period shorter than the calculated time necessary to replace the air in the tank, in order to obtain a satisfactory concentration at the surface level. The concentrations at the ½-hour period were low at the 84- and 102-foot levels, and did not adjust themselves materially until after the 8-hour period. There were still regions of quite low concentrations at the 24-hour period at these levels.

The distribution of gas in test B-2 was quite uniform, as shown in table 9. In this instance, the time necessary to displace the air was calculated and the fumigant was applied at a rate proportional to this time. The blower was shut off when the dosage had all been applied, and the concentration at the surface level was also satisfactory at this moment.

The distribution of gas in test B-3 is presented in table 10. It was concluded that the unsatisfactory distribution was due in part to excessive leakage around the gaskets where the ducts in the hopper were connected through the hopper wall to the circular pickup ducts on the outside of the hopper. It had been necessary to replace the hopper after the inner ducts had been installed, and the collar gaskets around each connection had not been properly replaced.

It was concluded from these tests that methyl bromide could be adequately distributed with aeration systems, simply by reversing the flow of air so as to force the gas upward through the wheat mass. This method, termed "forced distribution," entails the calculation of the time necessary for displacement, and a proration of the application of the fumigant over this period of time so that the fan is not operated unless some fumigant is being administered.

Table 8.--Distribution of methyl bromide in an elevator tank of wheat resulting from forced distribution by operating the aeration fan in reversed position for 18 minutes at an air-flow rate of 0.04 c.f.m./bu., with a dosage rate of 1.67 lbs./1,000 cu. ft., test B-1

Sample location and number	Concentration per 1,000 cu. ft. after				
	½ hour	2 hours	4 hours	8 hours	24 hours
	Ounces	Ounces	Ounces	Ounces	Ounces
Headspace					
1. Cable A--north side	14	10	8	6	3
2. Cable B--east side	18	20	16	10	3
3. Cable C--south side	26	28	20	10	4
4. Cable 48--center of bin	20	12	11	6	2
2 feet deep (on slope)[1]					
5. Cable A--north side	9	12	10	6	3
6. Cable C--south side	18	12	13	8	6
7. Cable 48--center of bin	18	11	12	11	5
4 feet deep (on slope)					
8. Cable A--north side	13	15	13	10	4
9. Cable C--south side	23	10	12	10	6
10. Cable 48--center of bin	22	10	10	9	4
6 feet deep (on slope)					
11. Cable A--north side	9	12	8	8	4
12. Cable C--south side	19	10	10	9	6
13. Cable 48--center of bin	15	8	8	7	4
12 feet deep					
14. Cable A--north side	16	15	14	14	3
15. Cable B--east side	14	13	12	10	6
16. Cable C--south side	29	23	15	9	5
17. Cable 48--center of bin	14	10	8	8	4
30 feet deep					
18. Cable A--north side	24	24	15	16	4
19. Cable B--east side	25	30	28	22	13
20. Cable C--south side	28	31	10	22	12
21. Cable 48--center of bin	26	18	15	12	8
48 feet deep					
22. Cable A--north side	23	12	10	8	4
23. Cable B --east side	18	28	24	18	9
24. Cable C--south side	23	26	13	18	11
25. Cable 48--center of bin	12	14	12	10	6
66 feet deep					
26. Cable A--north side	11	8	6	6	3
27. Cable B--east side	10	6	8	6	4
28. Cable C--south side	16	11	16	10	6
29. Cable 48--center of bin	11	9	10	6	5
84 feet deep					
30. Cable A--north side	9	6	5	5	2
31. Cable B--east side	10	8	9	6	5
32. Cable C--south side	6	7	6	6	6
33. Cable 48--center of bin	8	9	8	6	4
102 feet deep					
34. Cable A--north side	5	6	4	4	1
35. Cable B--east side	5	6	8	9	5
36. Cable C--south side	4	5	6	8	7
37. Cable 48--center of bin	4	7	6	6	1

[1] These samples, 5 through 13 inclusive, were taken near the surface of the grain as the natural slope from the fill hole was not leveled off. Other tubes placed in the bottom by engineers were sampled but had low concentrations.

Table 9.--Distribution of methyl bromide in an elevator tank of wheat resulting from forced distribution by operating the aeration fan in reversed position for 9 minutes at an airflow rate of 0.049 c.f.m./bu., with a dosage rate of 2 lbs./1,000 cu. ft., test B-2

Sample location and number	Concentration per 1,000 cu. ft. after				
	½ hour	2 hours	4 hours	8 hours	24 hours
	Ounces	Ounces	Ounces	Ounces	Ounces
Headspace					
1. North side	10	14	10	6	4
2. East side	30	15	10	6	4
3. South side	22	13	10	6	4
4. Center of bin	24	15	10	6	4
8 feet deep					
5. North side	6	13	12	7	5
6. East side	30	16	14	9	8
7. South side	38	16	12	7	5
8. Center of bin	30	20	17	10	8
26 feet deep					
9. North side	18	14	14	13	14
10. East side	32	18	16	15	14
11. South side	34	20	18	15	13
12. Center of bin	32	24	22	20	20
44 feet deep					
13. North side	24	16	15	13	14
14. East side	32	18	15	14	12
15. South side	32	20	18	15	14
16. Center of bin	32	25	22	20	20
62 feet deep					
17. North side	30	15	15	12	13
18. East side	31	18	15	14	12
19. South side	38	23	19	15	15
20. Center of bin	30	23	20	18	18
80 feet deep					
21. North side	40	21	20	15	15
22. East side	44	24	21	18	15
23. South side	48	30	26	20	15
24. Center of bin	42	32	28	23	20
98 feet deep					
25. North side	54	27	25	18	14
26. East side	36	20	16	15	6
27. South side	28	18	16	15	4
28. Center of bin	30	22	18	19	6
Bottom					
29. Hopper	10	24	22	6	12

Table 10.--Distribution of methyl bromide in an elevator tank of wheat resulting from forced distribution by operating the aeration fan in reversed position for 21 minutes at an airflow rate of 0.023 c.f.m./bu., with a dosage rate of $2\frac{1}{4}$ lbs./1,000 cu. ft., test B-3

Sample location and number	Concentration per 1,000 cu. ft. after				
	½ hour	2 hours	4 hours	8 hours	24 hours
	Ounces	Ounces	Ounces	Ounces	Ounces
Headspace					
1. Above load	10	26	30	20	6
4 feet deep					
2. Center	2	5	4	4	2
3. East side	2	54	42	31	12
34 feet deep					
4. Center	13	11	7	6	3
5. East side	8	5	4	5	4
64 feet deep					
6. Center	10	9	8	8	6
7. East side	12	9	6	7	6
94 feet deep					
8. Center	20	13	8	7	2
9. East side	22	14	12	9	3
119 feet deep (bottom)					
10. Center	4	3	3	3	0
11. East side	4	4	3	2	0

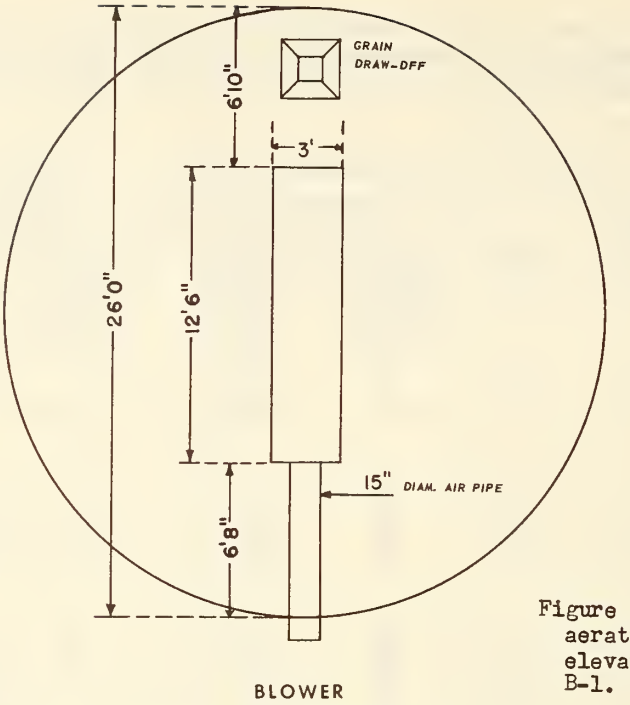

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Figure 1.--Diagram showing the aeration duct system in the elevator tank used in test B-1.

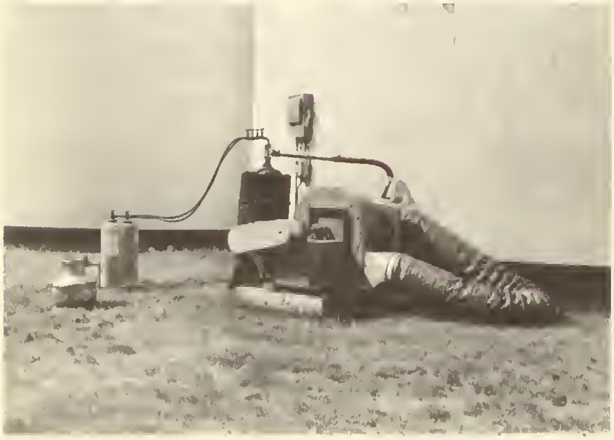

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Figure 2.--Fan of the aeration system in elevator tank used in test B-1.

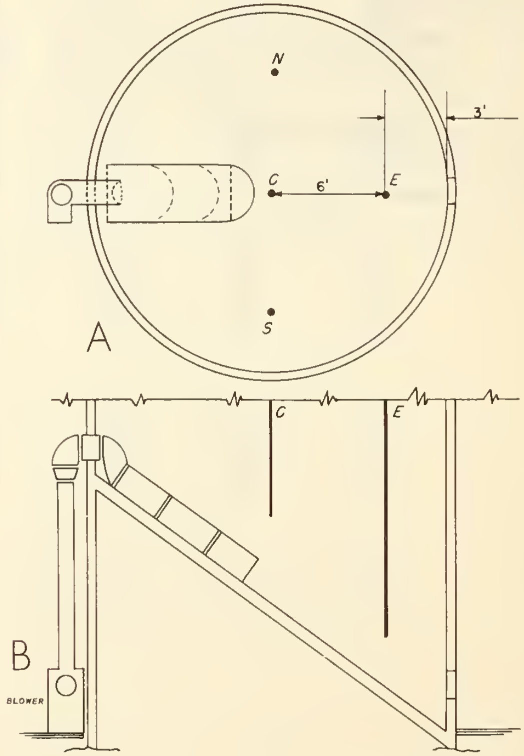

Figure 3.--Diagrams of the top (A) and side (B) views of the aeration duct system in the elevator tank used in test B-2, and the locations of the gas sampling cables (C, N, E, S).

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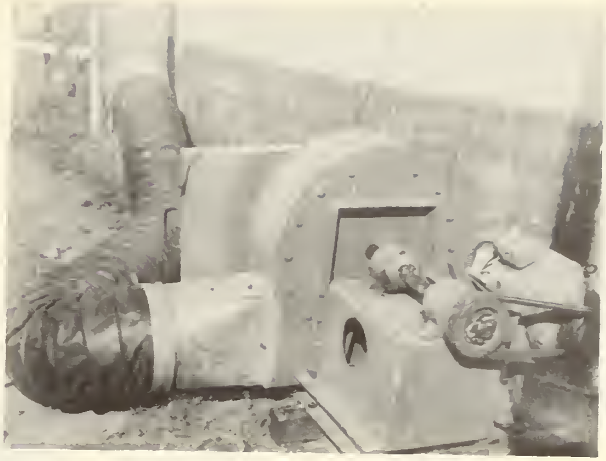
Figure 4.--Blower of the aeration system in the elevator tank used in test B-2.



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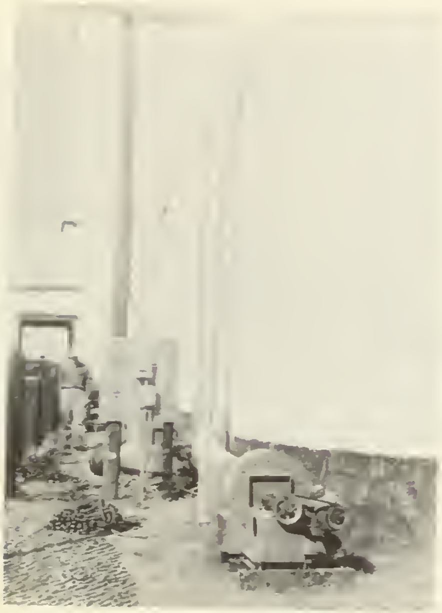

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Figure 5.--Duct connecting the blower to the internal aeration duct system in test B-2.

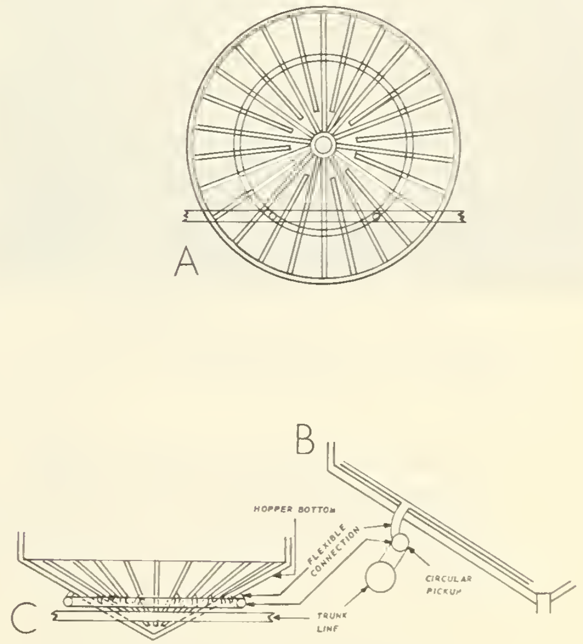

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Figure 6.--Diagrams of the top (A) and side views (B, C) of the aeration duct system in the elevator tank used in test B-3.

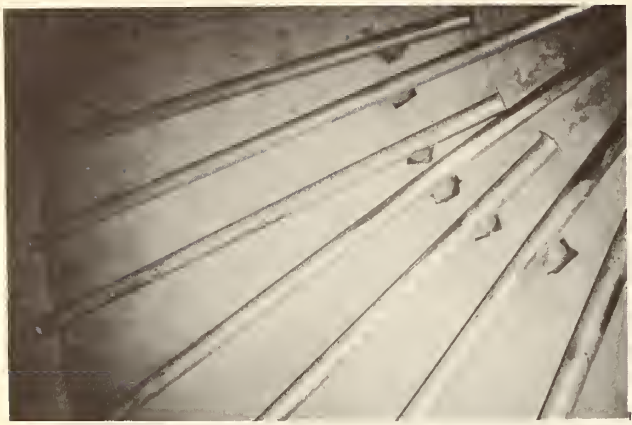

Figure 7.--Ducts on the floor of the hopper and the connection to the circular pickup duct beneath the floor, in the system used in test B-3.

BN-3315

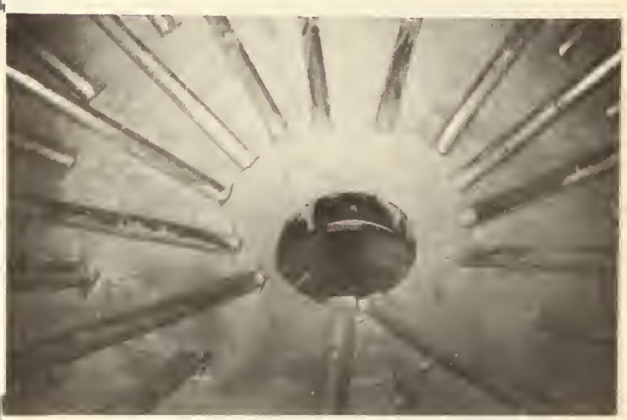

Figure 8.--Arrangement of the ducts around the discharge of the hopper.

BN-3316

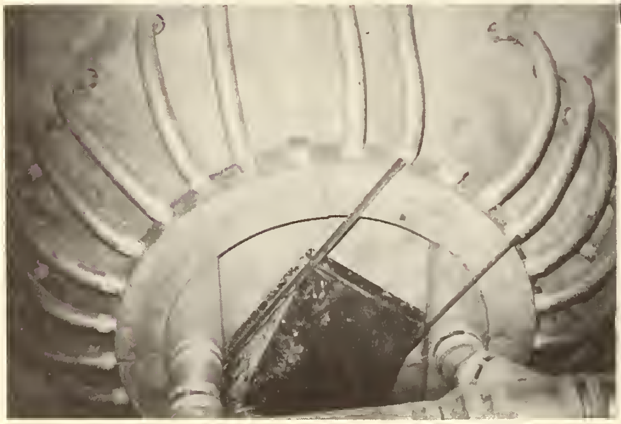

Figure 9.--Circular pickup duct beneath the hopper floor, and the connections to the ducts on the floor of the hopper.

BN-3317

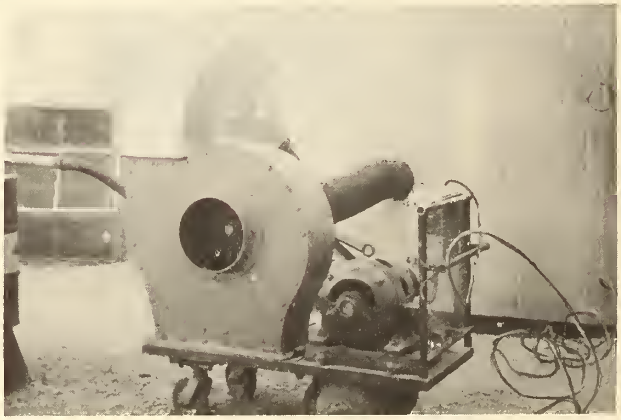

Figure 10.--Blower of the aeration system in the elevator tank used in test B-3.

BN-3318

TESTS IN LARGE STEEL STORAGE TANKS

Series C

The distribution of methyl bromide in large steel storage tanks by the forced distribution method was compared with distribution by recirculation in three tests in Oklahoma and Kansas between August 1954 and February 1955.

Test C-1 was conducted in a tank at Chickasha, Okla., containing 254,000 bushels of wheat (fig. 11). In this test the gas was recirculated, i.e., drawn down through the wheat and returned to the headspace. The tank was 60 feet in diameter, 70 feet high with a cone-shaped top 10 feet high, and had a volume of 318,300 cubic feet. The aeration system consisted of a large tunnel across the center of the tank floor which served as a main duct, and 6-inch tile aeration ducts leading from the main duct to the walls (fig. 12). The blower was attached to one end of the main duct, and a return duct led up the outside wall and discharged into the headspace. The capacity of the blower was not determined, nor the airflow rate measured. The blower was smaller, however, than the one in test C-2, described later. The blower was operated 40 minutes during and after gas introduction; then, when the ½-hour reading showed poor distribution, it was operated for 15 additional minutes.

In these tests, the gas sampling system was made by inserting sampling probes from surface to depths of 15, 30, and 45 feet at the south side, center, and north side of the tank, with probes numbers 4, 8, and 12 inserted from the tunnel.

In the test at Chickasha, the methyl bromide was introduced into the exhaust side of the blower and blown up through the metal return duct into the space above the load, then pulled down.

Test C-2 was made in a similar tank located at Clinton, Okla. In this test the forced distribution method was used, i.e., the fumigant was introduced into the floor aeration duct system and forced upward through the wheat mass during the period of gas introduction. The blower at this tank was larger than the one at Chickasha, but its capacity was not determined and the airflow rate was not measured. The methyl bromide was volatilized before introduction into the duct system (fig. 13), with a unit developed by Hammer and Amstutz [6].

The dosage rate in both tests was 2 lbs./1,000 cu. ft. However, in the test at Clinton, two of the methyl bromide cylinders had leaked and the actual dosage rate there was 1.86 lbs./1,000 cu. ft. The wheat was aerated at the end of the fumigation period to remove the fumigant.

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[6] Hammer, O. H., and Amstutz, F. C. Apparatus for more rapid volatilization of methyl bromide. Down to Earth 11 (3): 11-13. 1955

Test C-3 was conducted in a tank at McPherson, Kans. In this test, the gas was recirculated. The tank was 119 feet in diameter and 27 feet high, with a volume of 306,723 cubic feet, and it contained 253,184 bushels of wheat (fig. 14). The aeration system consisted of 3 sets of aeration ducts, 1 in a square in the center of the floor, the other 2 in a divided septagonal pattern, as shown in figures 15A, 15B, and 15C. The ducts were made of corrugated metal pipe, 15 inches in diameter, with 28 holes, 13/32 inch in diameter, per lineal foot. Three pneumatic conveyors 7/ were used as blowers (fig. 16), one attached to the center square of ducts, the second to one-half of each septagonal duct, and the third to the other halves. The combined airflow rate was calculated as 0.04 c.f.m./bu. This tank was thoroughly infested with the lesser grain borer, the flat grain beetle, and the red flour beetle, and at least 20 locations sampled had wheat temperatures in excess of 100°F. A dosage rate of $2\frac{1}{2}$ lbs./1,000 cu. ft. was applied to control these insects, and observations on insect mortality and wheat temperatures were made subsequent to fumigation. The gas sampling system was made by inserting probes or sampling tubes to depths of 1, 7, 15, and 23 feet at 12 sample locations and from 3 locations above the load. The wheat was aerated following fumigation.

The distribution in test C-1, where the gas was recirculated, is given in table 11. The attempt to improve the distribution as noted at the $\frac{1}{2}$-hour period, by 15 minutes' additional operation of the blower, improved the concentration at the center somewhat, but there were still sampling locations with quite low amounts of gas. The erratic distribution was attributed to too low an airflow rate.

The distribution in test C-2, where the fumigant was forced upward through the wheat, is presented in table 12. Very good concentrations were present in the center and side-wall tiers of sampling points. The low concentrations near the north side were found to be due to collapsing of part of the tile lateral ducts in this area. It was therefore assumed that distribution was satisfactory in most of the tank.

The distribution obtained in test C-3, where the gas was recirculated, is presented in table 13, and was very satisfactory. Observations made 4 to 6 weeks later of insect mortality corroborated the apparently satisfactory results, since no live insects were found in extensive samplings, and the "hot spots" had receded to a temperature of 52° to 62°F.

It was concluded from this series that as good distribution of gas can be obtained by forced distribution as by recirculation in large steel tanks equipped with aeration systems.

7/Series 900 Vac-U-Vators were used in this instance.

Table 11.--Distribution of methyl bromide in a large steel tank of wheat resulting from recirculation for 55 minutes, and the disappearance of gas resulting from forced aeration for 45 minutes, test C-1

Sample location and number	Concentration per 1,000 cu. ft. during fumigation					Concentration per 1,000 cu. ft. during aeration			
	½ hour	2 hours	4 hours	8 hours	24 hours	½ hour	2 hours	4 hours	24 hours
	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces
Free space									
1. Above load	18	4	0	0	0	0	0	0	0
2. Tunnel	0	5	2	0	0	0	0	0	0
Surface									
3. South side	25	6	6	2	0	0	0	0	0
4. Center	20	3	0	0	0	0	0	0	0
5. North side	0	0	0	0	0	0	0	0	0
15 feet deep									
6. South side	39	25	22	12	5	0	0	0	0
7. Center	0	2	3	0	2	0	0	0	0
8. North side	34	22	17	12	4	0	0	0	0
30 feet deep									
9. South side	37	32	28	20	10	8	2	0	0
10. Center	0	10	7	3	2	2	3	0	0
11. North side	20	22	16	12	10	9	7	2	0
45 feet deep									
12. South side	28	31	24	16	6	2	0	0	0
13. Center	4	16	8	8	3	3	4	4	0
14. North side	18	22	15	10	10	4	7	6	0
Bottom									
15. South side	0	11	6	0	0	0	0	0	0
16. Center	0	0	2	0	0	0	1	0	0
17. North side	0	9	0	0	0	0	0	0	0

Table 12.--Distribution of methyl bromide in a large steel tank of wheat resulting from forced distribution by operating the aeration blower in reversed position for 40 minutes, with a dosage rate of 1.86 lbs./1,000 cu. ft., and the disappearance of gas resulting from forced aeration for 120 minutes, test C-2

Sample location and number	Concentration per 1,000 cu. ft. during fumigation					Concentration per 1,000 cu. ft. during aeration		
	½ hour	2 hours	4 hours	8 hours	24 hours	½ hour	2 hours	24 hours
	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces
Free space								
1. Above load	27	42	36	24	5	2	0	0
2. Tunnel	8	1	0	0	0	2	0	0
Surface								
3. North side	23	13	12	12	3	0	0	0
4. Center	34	24	17	17	4	0	0	0
5. North side wall . .	26	24	17	16	8	0	0	0
15 feet deep								
6. North side	0	4	0	0	0	0	0	0
7. Center	18	10	8	6	0	0	0	0
8. North side wall . .	13	4	4	4	0	0	0	0
30 feet deep								
9. North side	8	3	3	2	0	0	0	0
10. Center	24	17	15	12	6	0	0	0
11. North side wall . .	20	16	10	8	2	0	0	0
45 feet deep								
12. North side	10	6	4	3	0	0	0	0
13. Center	24	19	13	12	2	1	0	0
14. North side wall . .	24	22	10	15	7	0	0	0
Bottom								
15. North side	3	0	0	0	0	0	0	0
16. Center	27	19	20	17	6	1	0	0
17. North side wall . .	27	16	18	18	2	0	0	0

Table 13.--Distribution of methyl bromide in a large steel tank of wheat resulting from recirculation for 45 minutes at an airflow rate of 0.04 c.f.m./bu. provided by three pneumatic conveyors temporarily attached to the aeration system, with a dosage rate of 2½ lbs./1,000 cu. ft., test C-3

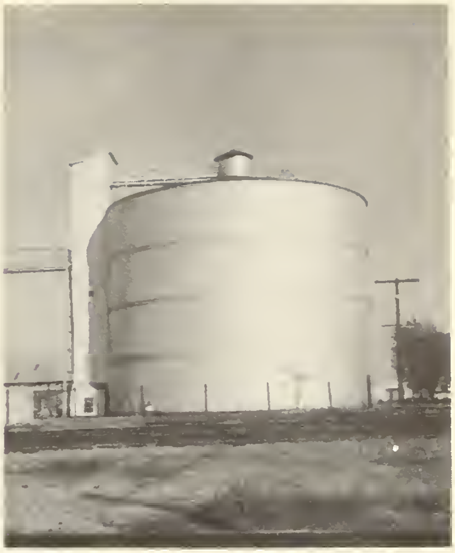
Sample location and number	Sampling port number	Concentration per 1,000 cu. ft. after				
		½ hour	2 hours	4 hours	8 hours	24 hours
		Ounces	Ounces	Ounces	Ounces	Ounces
Above load						
1. Center	--	60	50	46	33	14
2. South east side	--	60	48	42	33	14
3. North west side	--	54	48	43	32	15
1 foot deep						
4.	26	44	37	32	22	18
5.	12	52	45	39	31	16
6.	24	66	52	45	27	16
7.	15	50	38	35	25	17
8.	2	50	35	30	20	12
9.	16	39	26	22	16	10
10.	4	68	53	42	30	18
11.	19	54	47	40	29	14
12.	6	66	48	38	26	16
13.	20	58	43	37	23	11
14.	8	27	50	44	32	16
15.	22	57	45	24	24	12
7 feet deep						
16.	26	56	40	34	28	20
17.	12	66	46	39	30	16
18.	24	63	45	31	18	13
19.	15	53	38	30	23	18
20.	2	54	35	28	23	12
21.	16	53	38	32	20	13
22.	4	60	39	32	22	12
23.	19	53	35	26	16	11
24.	6	60	46	43	33	14
25.	20	66	44	33	19	18
26.	8	65	45	36	24	13
27.	22	57	38	29	23	13
15 feet deep						
28.	26	48	38	30	22	16
29.	12	57	42	35	30	13
30.	24	57	40	30	17	14

Table 13.--Continued

Sample location and number	Sampling port number	Concentration per 1,000 cu. ft. after				
		½ hour	2 hours	4 hours	8 hours	24 hours
		Ounces	Ounces	Ounces	Ounces	Ounces
31.	15	51	35	27	20	21
32.	2	51	44	36	32	14
33.	16	46	29	22	13	14
34.	4	49	45	26	15	21
35.	19	44	36	21	19	15
36.	6	58	41	31	20	14
37.	20	61	51	46	32	16
38.	8	54	46	30	26	14
39.	22	54	35	27	24	18
23 feet deep						
40.	26	44	33	34	34	16
41.	12	56	49	30	27	17
42.	24	56	42	28	31	17
43.	15	45	32	25	28	17
44.	2	31	26	22	26	20
45.	16[1]	no sample				
46.	4	45	39	38	34	17
47.	19	30	23	31	27	17
48.	6	56	36	34	30	17
49.	20	22	27	34	32	16
50.	8	44	39	39	32	15
51.	22	26	16	13	9	8

[1] Tube broken.

Figure 11.--Storage tank of wheat used in test C-1. The tank used in test C-2 was identical with this one.



BN-3319

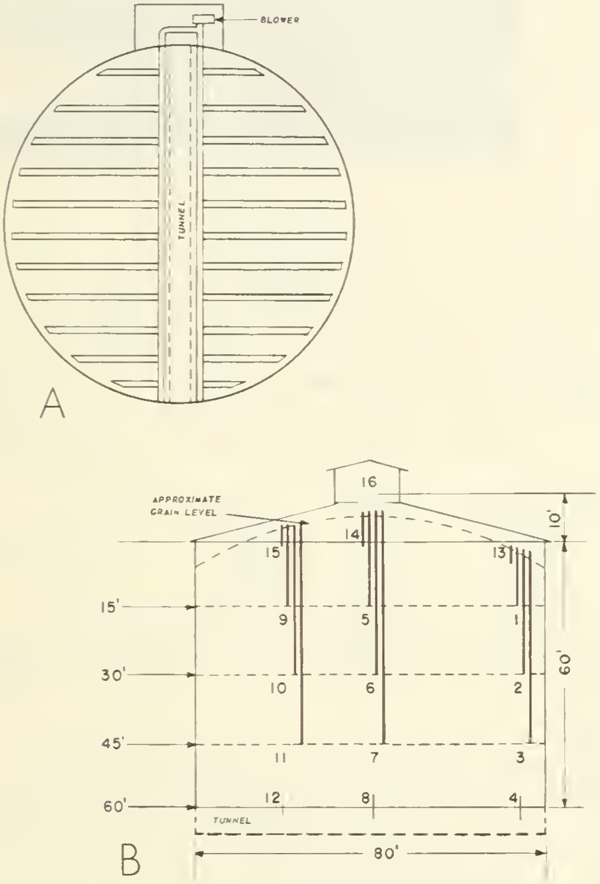


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Figure 12.--Diagrams of the top and side views of the storage tanks used in tests C-1 and C-2, showing the aeration duct system (A) and the location of the sampling points (B).

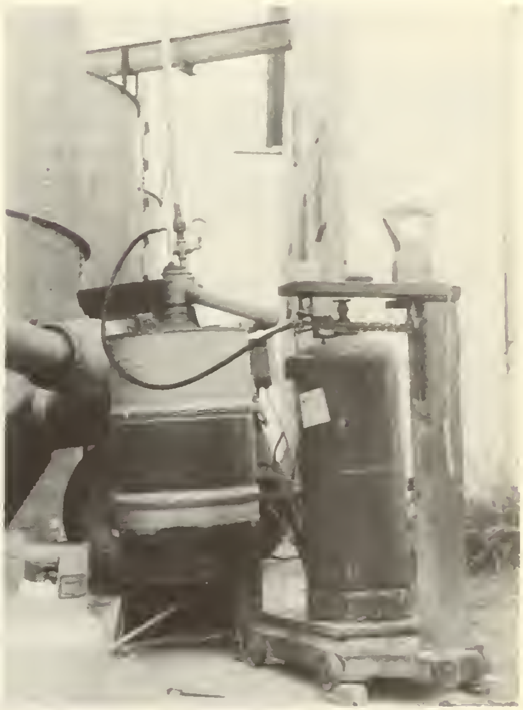
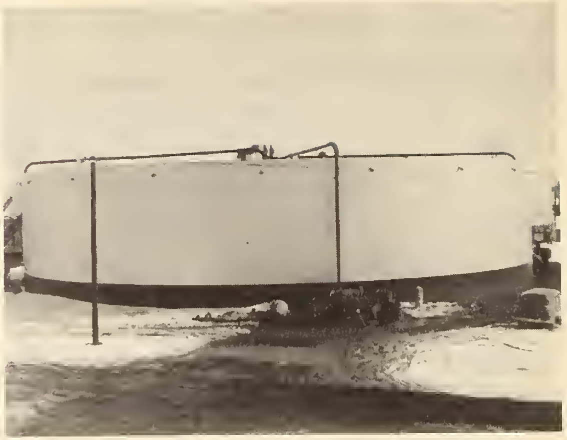


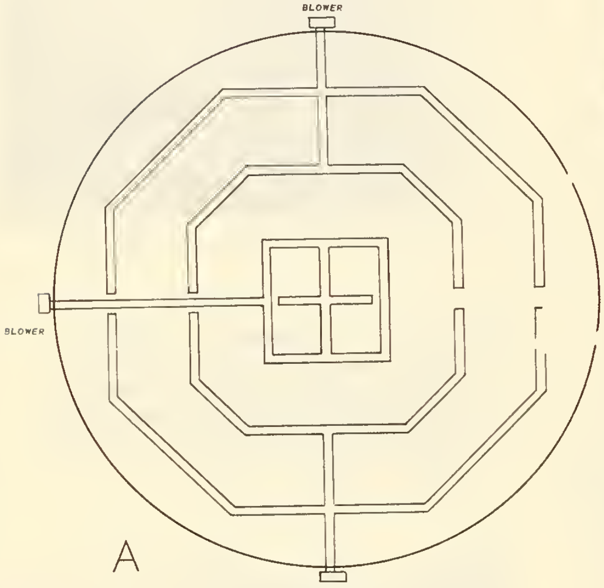
Figure 13.--Volatilizer used to vaporize the methyl bromide in test C-2.

BN-3320

Figure 14.--Storage tank of wheat used in test C-3, with pneumatic conveyors attached to the aeration system to serve as blowers.



BN-3321



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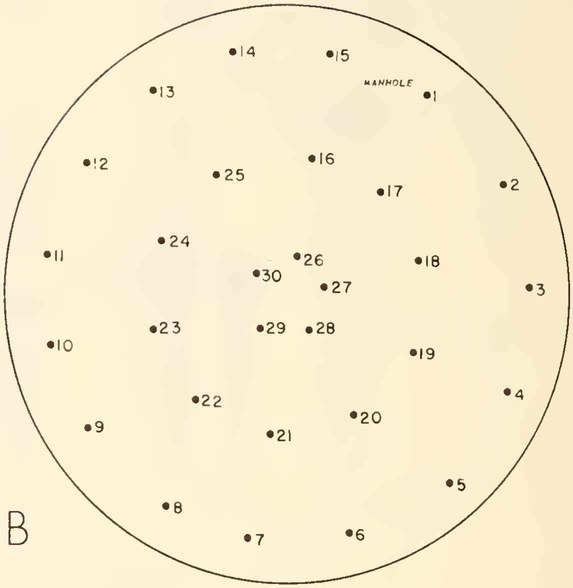
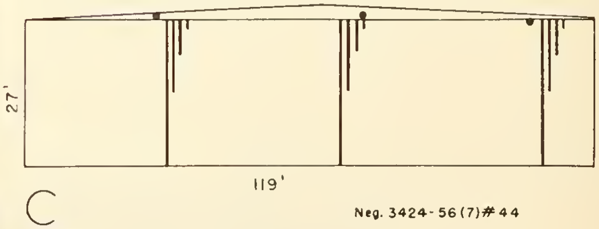


Figure 15.--Diagrams of tank used in test C-3, showing arrangement of the aeration ducts (A), the location of sampling ports on the roof used for gas sampling and temperature readings (B), and the relative vertical location of gas sampling points (C).



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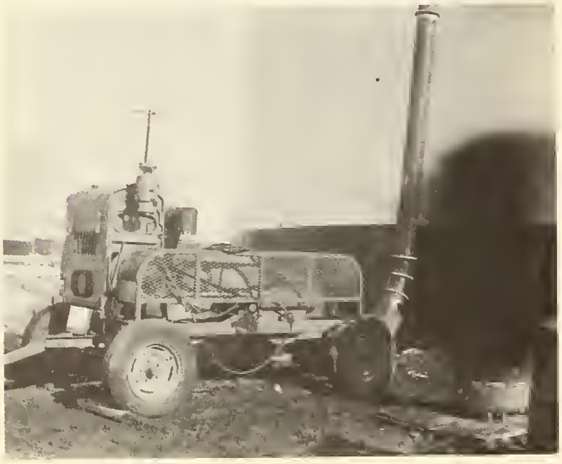


BN-3322

Figure 16.-- Pneumatic conveyor used as a blower in test C-3.

TESTS IN SMALL STEEL STORAGE TANKS

Series D

Four tests were conducted during September 1954 in facilities at Verden, Okla., to study distribution in 10,000-bushel steel tanks by recirculation, particularly in reference to a longer initial recirculation period. The tests were made in 4 similar tanks 32 feet high, 21 feet in diameter, with a volume of 12,500 cubic feet (fig. 17). Each contained identical aeration systems of the radial type as shown in figure 18, consisting of a hub 4 feet in diameter with a 4-inch base wall and a 14-inch conical top placed in the center of the floor, with 16 laterals leading to the walls in spoke fashion. Each lateral was 4 inches in diameter next the hub, but midway to the wall it was reduced in size. The underside of each lateral was perforated with ½-inch holes protected by V-shaped strips also perforated with 1/8-inch holes. A 10-inch duct led from the hub to the outside, where a blower was attached. For these tests a return duct was installed to discharge the blower into the headspace (fig. 19). The airflow rate was determined to be 0.18 c.f.m./bu. Two gas sampling cables were installed, one down the center and one near the south wall, with sampling points in the headspace and at the 10-, 20-, and 30-foot depths.

In tests D-1, 2, and 3, the methyl bromide was recirculated for 5-9 minutes. In test D-4 it was recirculated 2 hours.

The results of tests D-1, 2, and 3 are combined in table 14. The distribution of gas was excellent, and the 5-9 minutes recirculation period appeared to be more than adequate.

In table 15, where the results of test D-4 are presented, the average concentration at the 2-hour period -- the end of recirculation -- was considerably below the 2-hour concentrations in table 14. This difference persisted through the 24-hour period. It is evident that the increased circulation caused extensive reduction in concentration, but apparently not through leakage, since no odor of escaping methyl bromide was observed.

It was concluded from this series of tests that recirculation should be restricted to the period necessary to obtain good distribution, and should not be extended.

Table 14.--Distribution of methyl bromide in 10,000-bushel steel tanks of wheat resulting from recirculation for 5 to 9 minutes at an airflow rate of 0.18 c.f.m./bu., with a dosage rate of 2½ lbs./1,000 cu. ft.; average of tests D1, D2, and D3 1/

Sample location and number	Concentration per 1,000 cu. ft. after				
	½ hour	2 hours	4 hours	8 hours	24 hours
	Ounces	Ounces	Ounces	Ounces	Ounces
Center of bin					
1. Above load	42	31	29	22	13
2. 10 feet deep . . .	42	31	26	24	17
3. 20 feet deep . . .	43	39	33	23	16
4. 30 feet deep . . .	37	32	25	22	13
South quadrant					
5. Above load	43	32	29	22	14
6. 10 feet	45	29	23	18	14
7. 20 feet	45	35	31	18	15
8. 30 feet	33	28	24	20	12

1/ The gas was evacuated in 30 minutes in each of the three tests, but the blower was allowed to run longer to cool the grain.

Table 15.--Distribution of methyl bromide in a 10,000-bushel steel tank of wheat resulting from recirculation for 2 hours at an airflow rate of 0.18 c.f.m./bu., with a dosage rate of 2½ lbs./1,000 cu. ft., test D-4

Sample location and number	Concentration per 1,000 cu. ft. after						
	½ hour	1 hour	1½ hours	2 hours	4 hours	8 hours	24 hours
	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces
Center of bin							
1. Above load	40	30	19	15	12	10	6
2. 10 feet deep . . .	42	32	20	15	12	10	7
3. 20 feet deep . . .	41	28	19	11	9	8	6
4. 30 feet deep . . .	48	25	14	10	8	7	6
South quadrant							
5. Above load	40	28	16	12	8	6	5
6. 10 feet deep . . .	43	29	17	12	10	8	6
7. 20 feet deep . . .	46	28	18	10	8	6	6
8. 30 feet deep . . .	45	26	15	9	7	5	6

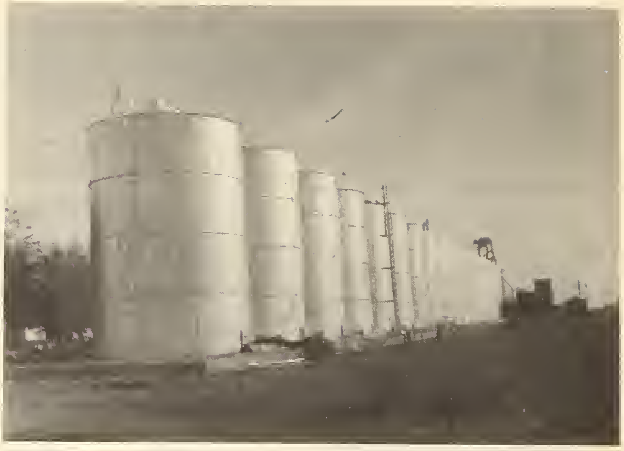


Figure 17.--Ten-thousand bushel upright steel tanks of wheat used for tests D-1 to D-4.

BN-3323

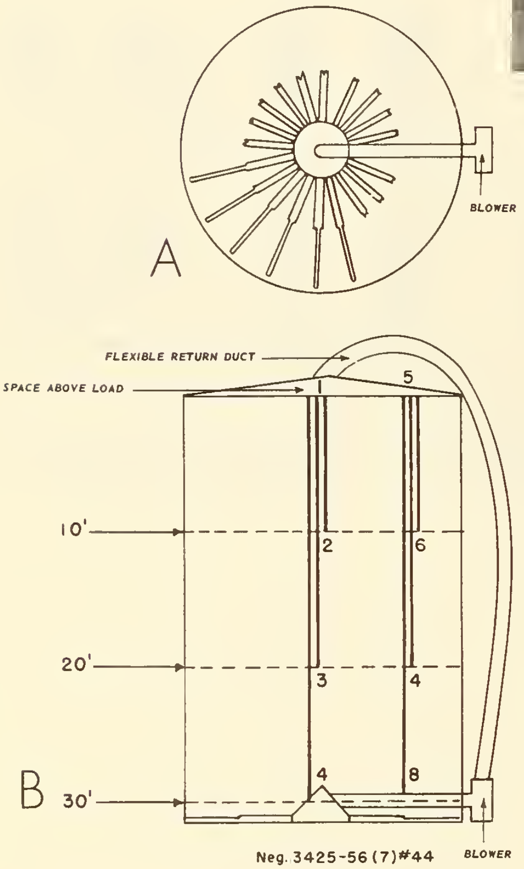


Figure 18.--Diagrams of the top and side views of the storage tanks used in tests D-1 to D-4, showing the aeration duct system (A) and the location of the sampling points (B).

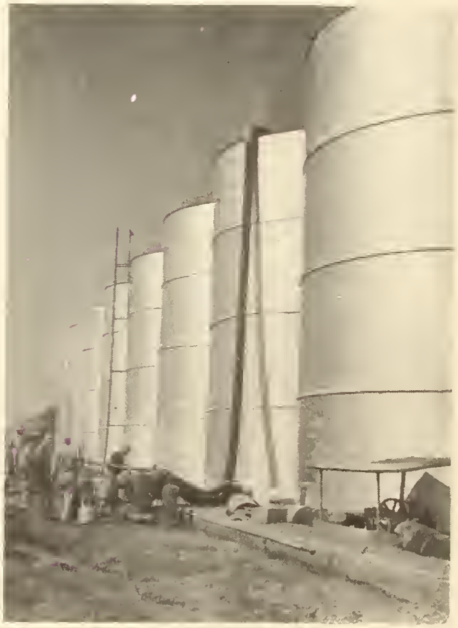


Figure 19.--Duct installed on a test unit to return the blower discharge to the headspace of the tank.

BN-3324

TESTS IN FLAT STORAGE

Series E

Two tests were conducted in August 1954, in large buildings at Chickasha, Okla., equipped with aeration systems and used temporarily for wheat storage, to compare the effectiveness of forced distribution with recirculation in flat storages of this magnitude.

Test E-1 was made in a converted plane hangar 200 feet long by 100 feet wide. Wooden retainer walls at the sides (fig. 20) were 8 feet high, and the dome-shaped roof extended 14 feet above them at the center. The total volume was approximately 500,000 cubic feet, and the building contained 164,000 bushels of wheat. Attempts to seal the building were not too effective because of its construction.

The aeration system consisted of 3 main floor ducts running the long way of the building, with 4-inch perforated lateral ducts at 6-foot intervals, as shown in figure 21. Each floor duct had a vertical riser connected at the middle which led to an overhead manifold (fig. 22) leading to the blower outside the main building. The 40-inch blower was powered by a 60-hp. motor (fig. 23), but its capacity was too great and a damper was placed in the intake to reduce the air volume. The airflow rate was 0.083 c.f.m./bu. for this test.

Gas sampling tubes were placed at 45 locations in the building, at the floor, 6-foot, and surface levels, and in the headspace, as listed in table 16 (fig. 24).

The methyl bromide was introduced into the duct system and forced up through the wheat mass from the floor level. The dosage rate of methyl bromide was 1.6 lbs./1,000 cu. ft. for a 24-hour exposure. The blower was operated for 10 minutes during introduction of the fumigant, until a satisfactory concentration was recorded at the surface, then stopped. After the $\frac{1}{2}$-hour period what appeared to be liquid methyl bromide was noted dripping from the overhead manifold, and the blower was operated an additional 5 minutes to clear out the methyl bromide in the duct. This was later found to be water resulting from the frosting of the duct. Following the fumigation the wheat was aerated by operating the blower for 4 hours.

Test insect samples were placed near each gas sampling point (fig. 25). These were removed following aeration and held for observations on mortality.

Test E-2 was made in a converted cotton mill 200 feet long, 70 feet wide, with walls 16 feet high and a gable-type roof 17 feet above this level. The building contained 106,694 bushels of wheat. It was sealed before fumigation.

The aeration system was divided, each half serving one end of the building and equipped with its own blower. Each half consisted of 2 main floor ducts equipped with 4-inch perforated lateral aeration ducts spaced at 6-foot intervals as shown in figure 26. The 2 main ducts in each end were connected together and to the motor, and a return duct from the motor discharged into the headspace (fig. 27). The airflow rate was not calculated.

Forty-three gas sampling tubes were placed in the building at the floor, 6-foot, and surface levels, and in the headspace, as listed in table 17.

The methyl bromide was introduced into the return ducts and recirculated for 45 minutes. A dosage of 2 lbs./1,000 cu. ft. was used, for a 24-hour exposure. After the fumigation the wheat was aerated by operating the blower for 30 minutes.

Test insect samples were placed near each gas sampling point. These were removed after aeration and held for observation of mortality.

The results of test E-1 are given in table 16. The considerable drop in concentration between the ½-hour and 2-hour readings was considered to be due to the extra 5 minutes during which the blower was operated. This apparently forced the fumigant into the headspace where it was lost. In spite of this mishap, and some low areas of concentration (sampling points 8, 10, and 20 at the floor level, 7 and 33 at the 6-foot level, and 38, 39, and 40 at the surface), all test insects were killed except those exposed in the overspace. The gas was rapidly removed by operation of the blower after the fumigation.

The results of test E-2 are given in table 17. The gas distribution was fairly satisfactory, considering the size of the structure, and all test insects were killed. The gas was quickly removed by aeration as in the previous test.

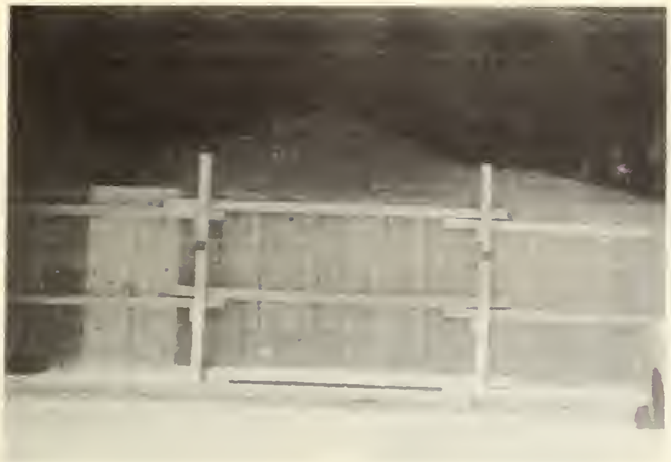
The deduction from these results was that forced distribution of gas in large flat storages by forcing the gas up through the wheat mass is undoubtedly feasible. The distribution at ½-hour in E-1 was not quite as good as in E-2, but considering that the building was not as tight, it indicated fair success.

Table 16.--Distribution of methyl bromide and mortality of test insects in a converted hangar full of wheat resulting from forced distribution by operating the aeration blower in reversed position for 15 minutes at an airflow rate of 0.083 c.f.m./bu., with a dosage rate of 1.6 lbs./1,000 cu. ft., and disappearance of gas resulting from forced aeration for 4 hours, test E-1

Sample location and number	Concentration per 1,000 cu. ft. during fumigation					Concentration per 1,000 cu. ft. during aeration			Mortality of test insects
	½ hour	2 hours	4 hours	8 hours	24 hours	½ hour	4 hours	24 hours	
	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Percent
East side									
1. Row 1-1, 6 feet deep	16	4	6	8	6	0	0	0	100
2. Row 1-1, Bottom . . .	16	6	6	7	8	0	0	0	100
3. Row 1-2, 6 feet deep	17	8	7	10	7	1	0	0	100
4. Row 1-2, Bottom . . .	17	12	15	13	9	0	0	0	100
5. Row 1-3, 6 feet deep	13	4	7	10	6	0	0	0	100
6. Row 1-3, Bottom . . .	160	14	20	14	9	0	0	0	100
7. Row 1-4, 6 feet deep	5	0	0	0	3	0	0	0	100
8. Row 1-4, Bottom . . .	1	0	0	0	3	0	0	0	100
9. Row 2-1, 6 feet deep	16	4	6	4	3	1	0	0	100
10. Row 2-1, Bottom . . .	5	0	2	0	2	0	0	0	100
11. Row 2-2, 6 feet deep	13	8	8	4	3	0	0	0	100
12. Row 2-2, Bottom . . .	22	9	5	5	5	0	0	0	100
13. Row 2-3, 6 feet deep	15	10	9	6	5	0	0	0	100
14. Row 2-3, Bottom . . .	20	4	3	0	3	0	0	0	100
15. Row 2-4, 6 feet deep	15	10	7	6	4	0	0	0	100
16. Row 2-4, Bottom . . .	15	7	8	4	6	0	0	0	100
West side									
17. Row 3-1, 6 feet deep	20	8	4	5	2	0	0	0	100
18. Row 3-1, Bottom . . .	30	9	7	3	4	0	0	0	100
19. Row 3-2, 6 feet deep	15	10	6	8	5	0	0	0	100
20. Row 3-2, Bottom . . .	3	7	3	0	4	1	0	0	100
21. Row 3-3, 6 feet deep	15	4	2	6	3	0	0	0	100
22. Row 3-3, Bottom . . .	26	10	6	4	4	0	0	0	100
23. Row 3-4, 6 feet deep	8	0	2	2	0	0	0	0	100
24. Row 3-4, Bottom . . .	16	8	4	2	3	0	0	0	100
25. Row 4-1, 6 feet deep	20	8	7	7	2	0	0	0	100
26. Row 4-1, Bottom . . .	24	10	9	4	8	0	0	0	100
27. Row 4-2. 6 feet deep	20	7	3	5	3	0	0	0	100
28. Row 4-2, Bottom . . .	20	10	9	5	7	0	0	0	100
29. Row 4-3, 6 feet deep	17	6	8	4	2	0	0	0	100
30. Row 4-3, Bottom . . .	20	10	5	0	8	0	0	0	100
31. Row 4-4, 6 feet deep	24	5	4	4	3	0	0	0	100
32. Row 4-4, Bottom . . .	20	10	6	0	6	0	0	0	100
Southwest corner									
33. 6 feet deep	0	0	0	0	0	0	0	0	100
34. Bottom	19	8	5	2	10	0	0	0	100
Northeast corner									
35. 6 feet deep	18	13	10	7	4	0	0	0	100
36. Bottom	24	20	17	10	9	0	0	0	100
Surface									
37. South east corner . .	6	2	0	0	0	0	0	0	100
38. Center N.F. Qtr. . .	4	4	4	1	2	0	0	0	100
39. Center	8	6	0	0	0	0	0	0	100
40. Center S.W. Qtr. . .	4	2	0	0	0	0	0	0	100
41. Northwest corner . .	10	5	0	7	4	0	0	0	100
Headspace									
42. Southeast quarter . .	8	4	0	0	0	0	0	0	93
43. East wall	20	0	0	1	2	0	0	0	88
44. Northwest quarter . .	5	0	0	0	4	0	0	0	90
45. West wall	8	0	0	0	4	0	0	0	81

Table 17.--Distribution of methyl bromide and mortality of test insects in a converted cotton mill full of wheat resulting from recirculation for 45 minutes with a dosage rate of 2 lbs./1,000 cu. ft., and disappearance of gas resulting from forced aeration for ½ hour, test E-2

Sample location and number	Concentration per 1,000 cu. ft. during fumigation					Concentration per 1,000 cu. ft. during aeration			Mortality of test insects
	½ hour	2 hours	4 hours	8 hours	24 hours	½ hour	2 hours	24 hours	
	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Percent
North side									
1. Row 1-1, 6 feet deep	16	12	10	5	4	0	0	0	100
2. Row 1-1, Bottom . . .	18	12	8	4	5	0	0	0	100
3. Row 1-2, 6 feet deep	18	13	10	4	4	0	0	0	100
4. Row 1-2, Bottom . . .	20	12	8	5	4	2	0	0	100
5. Row 1-3, 6 feet deep	16	14	10	3	3	0	0	0	100
6. Row 1-3, Bottom . . .	22	14	8	6	2	2	0	0	100
7. Row 1-4, 6 feet deep	18	38	20	7	3	0	0	0	100
8. Row 1-4, Bottom . . .	22	13	6	8	2	0	0	0	100
9. Row 1-5, 6 feet deep	18	14	10	5	3	0	0	0	100
10. Row 1-5, Bottom . . .	18	12	4	2	2	0	0	0	100
Center									
11. Row 2-1, 6 feet deep	14	14	8	4	3	0	0	0	100
12. Row 2-1, Bottom . . .	20	18	13	10	3	0	0	0	100
13. Row 2-2, 6 feet deep	14	10	8	0	2	0	0	0	100
14. Row 2-2, Bottom	16	5	7	4	0	0	0	0	100
15. Row 2-3, 6 feet deep	16	38	17	8	2	3	0	0	100
16. Row 2-3, Bottom . . .	20	16	10	8	3	1	0	0	100
17. Row 2-4, 6 feet deep	10	7	5	3	2	0	0	0	100
18. Row 2-4, Bottom . . .	15	6	3	4	2	0	0	0	100
19. Row 2-5, 6 feet deep	10	8	6	4	2	0	0	0	100
20. Row 2-5, Bottom . . .	14	6	5	4	3	0	0	0	100
South side									
21. Row 3-1, 6 feet deep	10	8	5	5	2	0	0	0	100
22. Row 3-1, Bottom . . .	12	0	2	3	2	0	0	0	100
23. Row 3-2, 6 feet deep	11	6	3	2	3	0	0	0	100
24. Row 3-2, Bottom . . .	15	6	6	4	4	T	0	0	100
25. Row 3-3, 6 feet deep	22	10	3	0	4	0	0	0	100
26. Row 3-3, Bottom . . .	18	8	8	7	2	0	0	0	100
27. Row 3-4, 6 feet deep	16	13	10	4	4	0	0	0	100
28. Row 3-4, Bottom . . .	20	6	0	0	2	0	0	0	100
29. Row 3-5, 6 feet deep	29	10	9	2	4	0	0	0	100
30. Row 3-5, Bottom . . .	16	0	0	0	0	0	0	0	100
Southeast wall									
31. 6 feet deep	16	10	10	0	5	0	0	0	100
32. Bottom	16	12	9	4	3	0	0	0	100
Northwest wall									
33. 6 feet deep	17	12	9	2	2	0	0	0	100
34. Bottom	16	10	12	8	4	0	0	0	100
Surface									
35. Northeast quarter . .	14	9	5	0	2	0	0	0	100
36. Northwest quarter . .	15	7	4	0	0	0	0	0	100
37. Center	13	5	0	0	0	0	0	0	100
38. Southeast quarter . .	10	4	2	0	0	0	0	0	100
39. Southwest quarter . .	14	8	2	0	0	0	0	0	100
Headspace									
40. Northeast quarter . .	14	0	0	0	0	0	0	0	100
41. Northwest quarter . .	14	0	0	0	0	0	0	0	100
42. Southeast quarter . .	0	0	0	0	0	0	0	0	100
43. Southwest quarter . .	10	7	0	0	0	0	0	0	100



BN-3325

Figure 20.--Wheat retained behind laminated-paper lined bulkhead in test E-1.

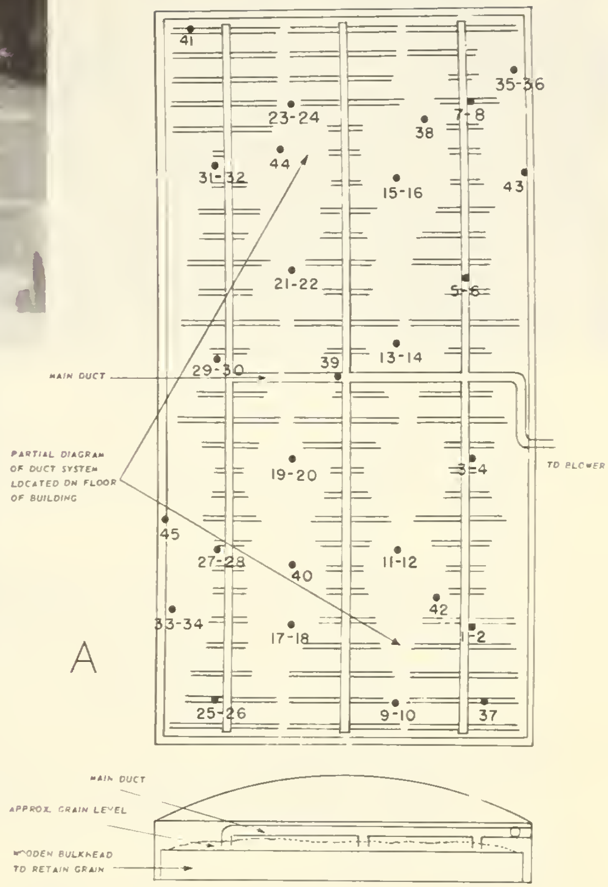


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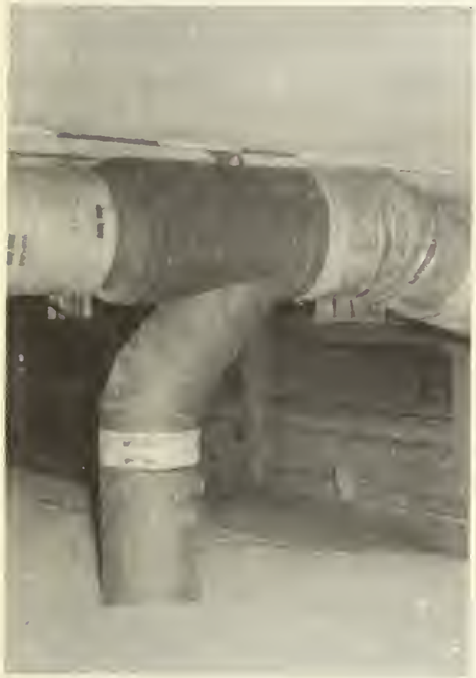
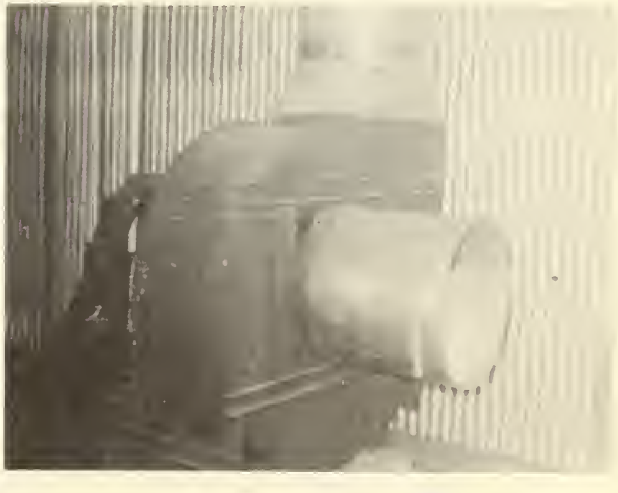
Figure 21.--Diagrams of the top and side views of the converted hanger in test E-1, showing the aeration duct system (A), and the overhead position of the main duct (B).



BN-3326

Figure 22.--Closeup of overhead main duct and a vertical connection to one of the floor ducts in test E-1.



BN-3327

Figure 23.-- Blower of the aeration system used in test E-1.

BN-3328

gure 24.--Inserting gas sampling probes into load of wheat used in test E-1.

BN-3647

Figure 25.--Inserting probes containing test insects into load of wheat in test E-1.

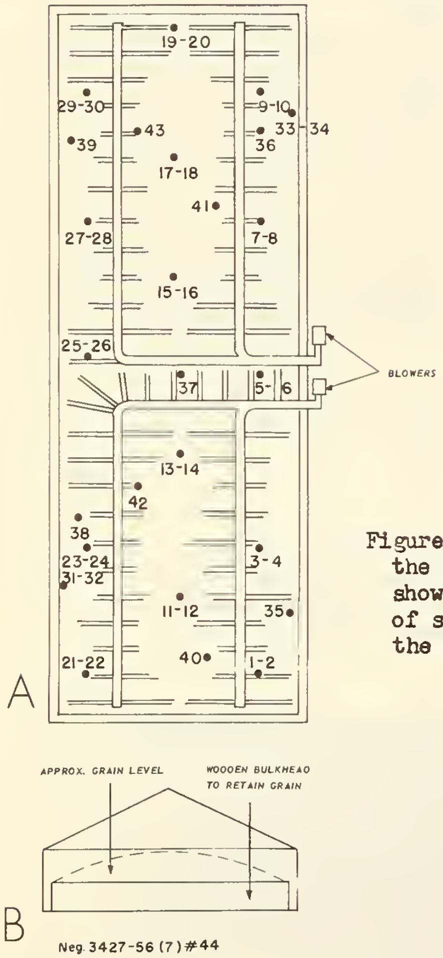


Figure 26.--Diagrams of the top and side views of the converted cotton mill used in test E-2, showing the aeration duct system and location of sampling points (A), and the position of the bulkhead (B).

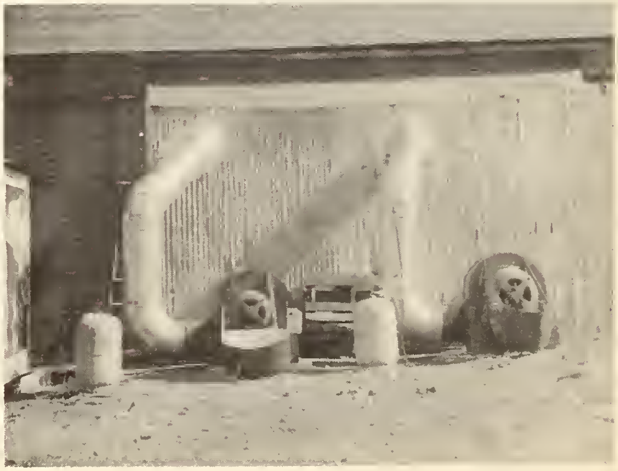


Figure 27.--Blowers of the aeration system used in test E-2.

BN-3648

Series F

Five tests were conducted in August and September 1955, in quonset-type wheat storages equipped with aeration systems, to study forced distribution in this type of structure. Two tests were made at Farwell, Tex., and three were made at Oklahoma City, Okla.

Test F-1 was made in a building 100 feet long, 40 feet wide, and 20 feet high, containing 62,834 cubic feet. The storage contained 32,000 bushels of wheat. The aeration system consisted of an arched duct 36 inches high, made of expanded metal and covered with screen wire, which ran down the center line of the floor from end to end (fig. 28). A fan outside one end was connected to the duct. It was powered by a 3-hp. motor (fig. 29) and produced an airflow rate of 0.1 c.f.m./bu.

Gas sampling tubes were placed at 26 locations in the building at the floor, 5-foot, and surface levels, and in the headspace, as listed in table 18.

The methyl bromide was introduced into the duct as a spray, and forced up through the wheat mass, at a dosage rate of 1.6 lbs./1,000 cu. ft. for a 24-hour exposure. The blower was operated until a satisfactory concentration was reached in the surface layer, which required 10 minutes. After fumigation the wheat was aerated for one hour.

Test F-2 was made in a building similar to the one used in F-1. The airflow rate was slightly lower, 0.09 c.f.m./bu., since the building contained 38,000 bushels of wheat.

Gas sampling tubes were placed in somewhat the same pattern, except that two additional tubes were placed in grain peaks at each end of the building.

The methyl bromide was forced up through the wheat mass as in the previous test. A dosage rate of 2 lbs./1,000 cu. ft. was used for a 24-hour exposure. The fan was operated for 12 minutes to reach the desired concentration in the surface layer.

A wind of 15 to 20 m.p.h. was blowing during both tests.

Test F-3 was made in a building 128 x 50 feet with a 20-foot wall. It contained 90,830 bushels of wheat. The aeration system consisted of a single floor aeration duct similar to those in test F-1 and 2. The fan was powered by a 7½-hp. motor which gave an airflow of 0.10 c.f.m./bu.

Forty-eight gas sampling tubes were placed in the building at the locations shown in table 20, at the floor, 10-foot, and surface levels, and in the headspace.

The methyl bromide was introduced into the floor duct and pushed up through the wheat mass. A dosage rate of 2 lbs./1,000 cu. ft. was used, and the fan was operated 18 minutes. The exposure period was 24 hours, after which the wheat was aerated for 1 hour.

There was a considerable natural insect infestation in the wheat, consisting of flour beetles, the flat grain beetle, the saw-toothed grain beetle, the lesser grain borer, the Indian-meal moth, the cadelle, and psocids. Samples of wheat were sifted following fumigation to determine the degree of control obtained.

Test F-4 was made in a quonset 96 x 50 feet with a 20-foot wall. The aeration system was similar to the quonset in F-3 but the load was only 65,622 bushels, so the airflow rate was approximately 0.13 c.f.m./bu.

The methyl bromide was introduced in the same manner, at a dosage rate of 2 lbs./1,000 cu. ft. The fan was operated for 14 minutes. The exposure period was 24 hours, after which the wheat was aerated, but no record of concentration was made during aeration.

Thirty-five gas sampling locations were established, at the floor, 10-foot, and surface levels, and in the headspace, as shown in table 21.

The same natural insect infestation existed in this quonset as in test F-3.

Test F-5 was made in a quonset 64 x 50 feet with a 20-foot wall. The aeration system was the same as in previous tests. The load was 41,000 bushels of wheat, and the airflow rate was approximately 0.22 c.f.m./bu. The fan was operated 11 minutes.

The methyl bromide was introduced as in tests F-4 and 5, with the same dosage rate. Following the 24-hour exposure period, the fan was operated long enough to aerate the wheat, but no concentration readings were recorded.

Twenty-three gas sampling tubes were used, at the floor, 10-foot, and surface levels, and in the headspace, as indicated in table 22.

The same natural insect infestation was present as in tests F-3 and 4. Samples of wheat were sifted after fumigation to check on insect mortality.

The results of these tests are presented in tables 18 to 22. There were some areas of low concentration in tests F-1 and 2, particularly at the surface level. These are considered to be due to the outside air movement which siphoned off the gas from the headspace. In F-2 a ventilator cover blew off during the test, and the concentration in the headspace dropped to zero at the 4-hour period and was low at stations 4, 7, 10, 13, 16, 19, 22, 27, and 28.

In test F-3 there was some variation in distribution but an adequate concentration apparently reached all points, for samplings after fumigation showed no live insects remaining. Test F-4 had an area of low concentration at the west side of the structure, at stations 1, 4, 5, 7, and 8.

Test F-5 also had an area of low concentration on the west side and areas of high concentration at the center. One live flat grain beetle and two live lesser grain borers were found in samplings after fumigation, near the surface in the northwest corner.

The deductions from these tests were that forced distribution of methyl bromide is feasible in quonset-like structures filled with wheat, where a single central floor duct is available. The gas distribution in these tests was adequate to produce excellent control of a widespread insect infestation. The use of a gas sampling unit is necessary in order to time properly the operation of the fan in this method. The dosage rate of 2 lbs./1,000 cu. ft. appeared to be adequate for good insect control.

Table 18.--Distribution of methyl bromide in a quonset of wheat resulting from forced distribution by operating the aeration fan in reversed position for 10 minutes at an airflow rate of 0.10 c.f.m./bu., with a dosage rate of 1.6 lbs./1,000 cu. ft., test F-1

Sample location and number	Concentration per 1,000 cu. ft. after				
	½ hour	2 hours	4 hours	8 hours	24 hours
	Ounces	Ounces	Ounces	Ounces	Ounces
South side, east end					
1. Surface	14	6	3	0	0
2. 5 feet deep . . .	13	12	10	6	3
3. Bottom	20	5	4	2	0
South side, west end					
4. Surface	6	0	0	0	0
5. 5 feet deep . . .	18	4	3	2	2
6. Bottom	22	12	10	8	5
Center line, east end					
7. Surface	22	8	3	0	0
8. 5 feet deep . . .	4	10	6	4	2
9. Bottom	5	8	10	10	4
Center					
10. Surface	24	6	2	2	0
11. 5 feet deep . . .	6	6	6	4	1
12. Bottom	8	9	12	11	4
Center line, west end					
13. Surface	16	8	4	2	0
14. 5 feet deep . . .	25	15	6	3	0
15. Bottom	4	13	12	7	2
North side, east end					
16. Surface	20	6	4	2	T
17. 5 feet deep . . .	40	18	8	5	3
18. Bottom	29	30	24	18	7
North side, center					
19. Surface	12	8	5	4	2
20. 5 feet deep . . .	32	20	7	7	4
21. Bottom	10	8	6	6	3
North side, west end					
22. Surface	8	4	2	1	2
23. 5 feet deep . . .	27	14	8	4	3
24. Bottom	23	18	10	15	8
Headspace					
25. Center, east end .	16	12	4	2	0
26. Center, west end .	10	8	3	T	1

Table 19.--Distribution of methyl bromide in a quonset of wheat resulting from forced distribution by operating the aeration fan in reversed position for 12 minutes at an airflow rate of 0.09 c.f.m./bu., with a dosage rate of 2 lbs./1,000 cu. ft., test F-2

Sample location and number	Concentration per 1,000 cu. ft. after				
	½ hour	2 hours	4 hours	8 hours	24 hours
	Ounces	Ounces	Ounces	Ounces	Ounces
South side, east end					
1. Surface	10	3	4	1	0
2. 5 feet deep . . .	20	17	11	4	2
3. Bottom	22	22	18	12	6
South side, center					
4. Surface	28	6	3	0	0
5. 5 feet deep . . .	17	18	7	T	0
6. Bottom	19	4	1	0	0
South side, west end					
7. Surface	20	4	0	0	0
8. 5 feet deep . . .	24	12	3	0	0
9. Bottom	22	10	9	5	4
Center line, east end					
10. Surface	22	2	2	0	0
11. 5 feet deep . . .	52	16	6	2	1
12. Bottom	17	23	13	4	2
Center					
13. Surface	17	4	0	T	0
14. 5 feet deep . . .	28	8	1	0	0
15. Bottom	15	0	0	0	0
Center line, west end					
16. Surface	8	0	0	0	0
17. 5 feet deep . . .	54	8	T	1	1
18. Bottom	32	13	6	4	3
North side, east end					
19. Surface	12	2	0	T	0
20. 5 feet deep . . .	24	12	8	4	2
21. Bottom	40	25	21	17	8
North side, west end					
22. Surface	15	2	0	2	0
23. 5 feet deep . . .	12	4	0	0	0
24. Bottom	34	19	11	10	8
Headspace					
25. East end	12	6	0	0	0
26. West end	6	3	0	0	0
Grain peaks					
27. East end	26	6	0	0	0
28. West end	24	6	0	0	0

Table 20.--Distribution of methyl bromide in a quonset of wheat resulting from forced distribution by operating the aeration fan in reversed position for 18 minutes at an airflow rate of 0.10 c.f.m./bu., with a dosage rate of 2 lbs./1,000 cu. ft., test F-3

Sample location and number	Concentration per 1,000 cu. ft. after				
	½ hour	2 hours	4 hours	8 hours	24 hours
	Ounces	Ounces	Ounces	Ounces	Ounces
West side, south end					
1. Surface	3	5	5	4	2
2. 10 feet deep	23	16	13	12	6
3. Bottom	25	18	18	13	6
4. Surface	8	5	5	3	2
5. 10 feet deep	34	15	5	3	0
6. Bottom	22	16	15	15	6
West side, north end					
7. Surface	6	5	5	4	2
8. 10 feet deep	22	18	12	4	1
9. Bottom	4	4	8	6	2
10. Surface	2	0	3	2	0
11. 10 feet deep	21	6	4	2	T
12. Bottom	3	5	6	6	4
Center line, end to end					
13. Surface	20	15	8	4	2
14. 10 feet deep	12	12	10	10	4
15. Bottom	56	70	33	13	2
16. Surface	30	18	9	6	1
17. 10 feet deep	18	14	12	14	4
18. Bottom	110	90	37	16	4
19. Surface	26	20	12	8	4
20. 10 feet deep	16	16	14	14	4
21. Bottom	19	27	16	14	T
22. Surface	27	18	12	9	2
23. 10 feet deep	17	17	20	16	5
24. Bottom	16	22	22	16	1
25. Surface	20	19	18	10	2
26. 10 feet deep	18	22	25	20	6
27. Bottom	36	48	32	20	2
28. Surface	28	25	18	11	5
29. 10 feet deep	22	24	24	20	7
30. Bottom	114	84	40	15	2
31. Surface	31	28	16	10	2
32. 10 feet deep	19	26	23	18	7
33. Bottom	19	24	26	19	4
East side, south end					
34. Surface	40	32	32	15	8
35. 10 feet deep	38	41	35	23	12
36. Bottom	49	52	43	25	14
37. Surface	31	22	23	13	5
38. 10 feet deep	34	20	37	27	12
39. Bottom	29	27	33	25	12
East side, north end					
40. Surface	19	14	20	14	4
41. 10 feet deep	29	24	32	24	10
42. Bottom	26	22	30	23	8
43. Surface	9	6	16	13	2
44. 10 feet deep	3	3	14	17	1
45. Bottom	10	9	21	10	3
Headspace					
46. South end	11	16	4	0	1
47. Center	8	8	5	0	0
48. North end	6	7	5	0	0

Table 21.--Distribution of methyl bromide in a quonset of wheat resulting from forced distribution by operating the aeration fan in reversed position for 14 minutes at an airflow rate of 0.13 c.f.m./bu., with a dosage rate of 2 lbs./1,000 cu. ft., test F-4

Sample location and number	Concentration per 1,000 cu. ft. after				
	½ hour	2 hours	4 hours	8 hours	24 hours
	Ounces	Ounces	Ounces	Ounces	Ounces
West side, south end					
1. Surface	2	2	0	2	1
2. 10 feet deep	9	15	10	9	2
3. Bottom	4	7	4	4	0
West side, center					
4. Surface	1	1	2	2	1
5. 10 feet deep	1	1	2	2	2
6. Bottom	5	6	3	3	2
West side, north end					
7. Surface	1	2	2	2	4
8. 10 feet deep	0	2	2	4	6
9. Bottom	8	12	7	8	2
Center line, end to end					
10. Surface	27	20	8	4	1
11. 10 feet deep	18	10	8	10	2
12. Bottom	280	60	32	24	4
13. Surface	26	22	16	13	2
14. 10 feet deep	10	10	16	17	8
15. Bottom	328	61	34	24	5
16. Surface	12	11	10	12	2
17. 10 feet deep	40	32	26	24	8
18. Bottom	70	34	32	27	6
19. Surface	20	18	14	13	2
20. 10 feet deep	40	29	24	24	5
21. Bottom	192	64	50	36	6
22. Surface	47	36	25	20	2
23. 10 feet deep	24	27	20	18	5
24. Bottom	20	16	13	18	4
East side, south end					
25. Surface	43	40	25	25	5
26. 10 feet deep	32	24	12	7	6
27. Bottom	49	38	31	29	12
East side, center					
28. Surface	22	22	18	18	8
29. 10 feet deep	30	35	28	27	12
30. Bottom	5	8	8	9	4
East side, north end					
31. Surface	10	16	12	13	4
32. 10 feet deep	30	34	26	22	8
33. Bottom	18	12	7	4	2
Headspace					
34. South end	7	10	6	3	1
35. North end	6	9	6	3	0

Table 22.--Distribution of methyl bromide in a quonset of wheat resulting from forced distribution by operating the aeration fan in reversed position for 11 minutes at an airflow rate of 0.22 c.f.m./bu., with a dosage rate of 2 lbs./1,000 cu. ft., test F-5

Sample location and number	Concentration per 1,000 cu. ft. after				
	½ hour	2 hours	4 hour	8 hours	24 hours
	Ounces	Ounces	Ounces	Ounces	Ounces
West side, south end					
1. Surface	4	4	4	4	2
2. 10 feet deep . . .	3	3	1	1	0
3. Bottom	5	3	2	2	0
West side, north end					
4. Surface	4	5	3	5	4
5. 10 feet deep . . .	3	2	2	2	0
6. Bottom	3	2	2	2	0
Center line, end to end					
7. Surface	18	14	7	4	1
8. 10 feet deep . . .	18	12	12	9	4
9. Bottom	16	12	15	13	2
10. Surface	18	17	14	10	5
11. 10 feet deep . . .	21	14	12	8	4
12. Bottom	304	124	82	42	4
13. Surface	26	16	10	5	4
14. 10 feet deep . . .	24	12	13	9	3
15. Bottom	400	240	156	70	7
East side, south end					
16. Surface	18	14	12	8	2
17. 10 feet deep . . .	27	18	16	10	3
18. Bottom	14	8	8	8	2
East side, north end					
19. Surface	14	9	4	2	1
20. 10 feet deep . . .	13	5	6	5	2
21. Bottom	8	5	5	3	0
Headspace					
22. South end	12	6	4	2	0
23. North end	14	8	5	2	0

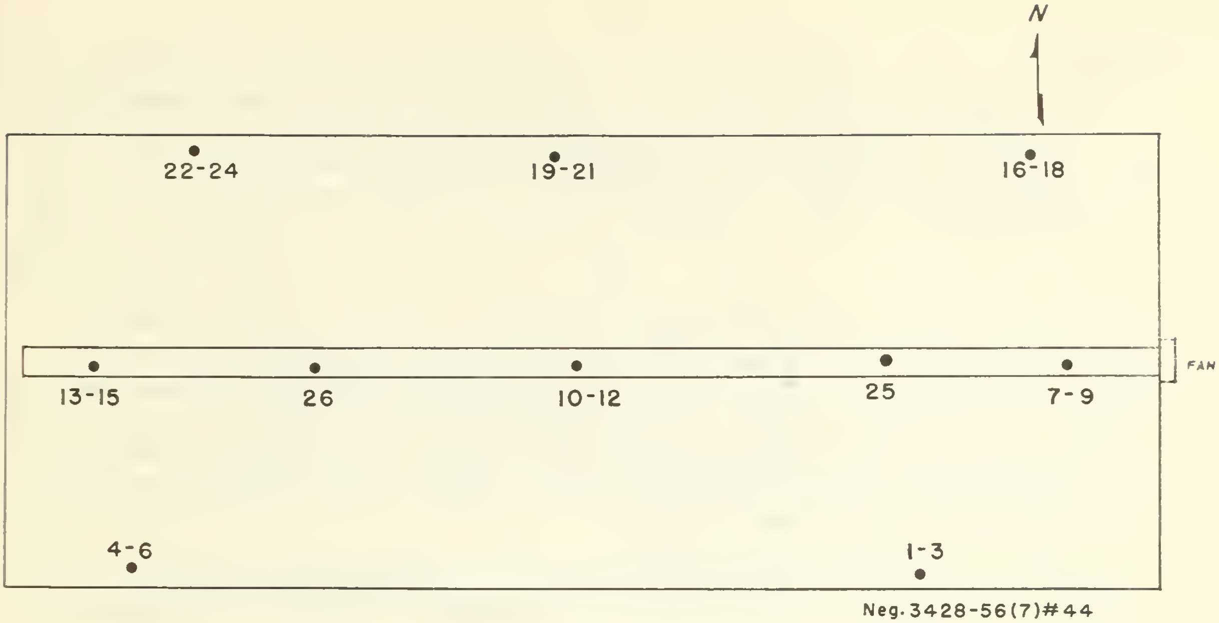


Figure 28.--Diagram showing the aeration duct in test F-1, and the location of gas sampling points.

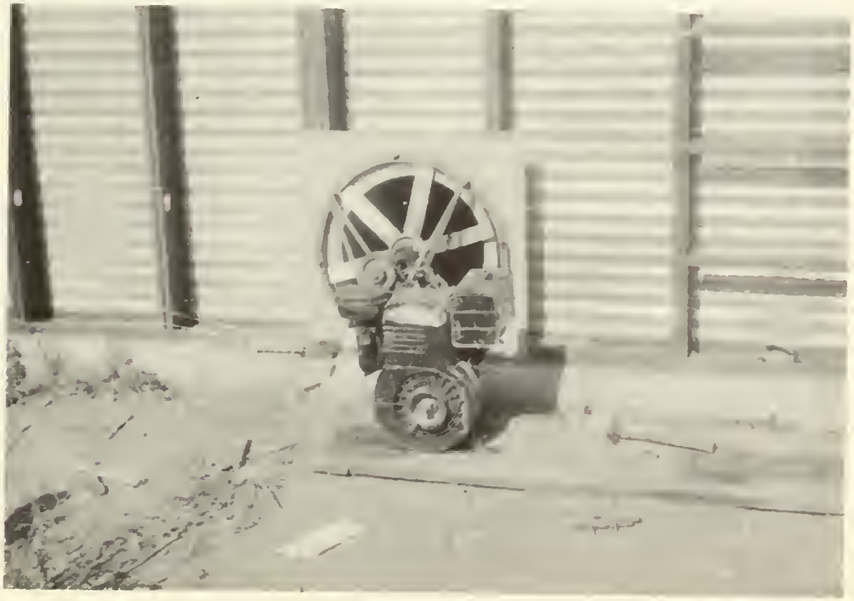


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Figure 29.--Fan of the aeration system in test F-1.

Series G

Five tests were made in August and October 1955 on grain sorghum stored in quonset-type buildings equipped with aeration systems to study recirculation and forced distribution in this commodity. One was made at Everett's Switch, Tex.; two at Hereford; one at Taft; and one at Joshua.

Test G-1 was conducted in a quonset, 120 x 40 feet and 20 feet high, with a volume of 75,368 cubic feet and a load of 36,000 bushels. The aeration system consisted of a single floor aeration duct along the center of the building. The grain sorghum did not completely fill the building, so one end of the duct was exposed. A fan (fig. 30) powered by a 3-hp. motor was attached to the duct inside the building. This fan discharged into the headspace and thus made a recirculation system. The airflow rate was 0.05 c.f.m./bu.

The grain sorghum was piled 10 to 12 feet deep except near the end of the duct. Its moisture content was 10.88 percent, temperature 78° to 82°F.

Thirty-five gas sampling tubes were placed in the building at the floor, 5-foot and surface levels in the grain sorghum, and in the headspace, as listed in table 23.

The methyl bromide was applied at a dosage rate of 3 lbs./1,000 cu. ft. and recirculated through the grain sorghum mass for 22 minutes. The exposure period was 24 hours. After fumigation, the grain sorghum was aerated for one hour.

No test insects were used and the natural infestation was light and scattered and was not considered sufficient for evaluation of mortality.

Tests G-2 and 3 were conducted in quonsets, 160 x 40 and 20 feet high. Each building had a volume of approximately 100,000 cubic feet and contained 80,000 bushels of grain sorghum.

The aeration system in each quonset consisted of a single duct along the center of the floor, which extended through the end wall where it was attached to the fan. The fan was powered by a 3-hp. motor (fig. 31). The airflow rate was 0.06 c.f.m./bu.

Gas sampling tubes were placed at 42 locations in the building, at the floor, 9-foot and surface levels, and in the headspace.

A dosage rate of 4 lbs./1,000 cu. ft. was applied. The gas was released into the duct and forced up through the grain until a satisfactory concentration was obtained at the surface. The blower was operated for 25 minutes to obtain this distribution in each test. In test G-2, as soon as the blower was stopped, 50 pounds of an 80-20 mixture of methyl bromide and chloropicrin was released in the headspace in an attempt to assure complete mortality in the surface layer. In test G-3, 50 pounds of straight methyl bromide was released in the headspace.

Test insect samples in perforated plastic vials were placed at all surface sampling locations and in the headspace (Nos. 1, 4, 7, 10, 13, 16, 19, 22, 25, 28, 31, 34, 37, 40, 41, 42). These were 6 inches deep in the grain sorghum. In addition, the grain sorghum in test G-2 was infested with flour beetles, the flat grain beetle, the saw-toothed grain beetle, the lesser grain borer, the rice weevil, the Indian-meal moth, the hairy fungus beetle, spider beetles, and psocids. In test G-3, the infestation included the saw-toothed grain beetle, the lesser grain borer, the Angoumois grain moth, and psocids.

Test G-4 was conducted in a building 225 x 60 feet, with 20-foot side walls and a quonset-type roof. The building had a volume of approximately 325,000 cubic feet, and was designed to hold 110 carloads of grain sorghum. When fumigated, it contained 85 carloads of grain sorghum and wheat, or approximately 180,000 bushels. The grain sorghum occupied 176 feet of the building and the test was all related to this commodity.

The aeration system consisted of 34 independent floor aeration ducts which extended in from the side walls from each side. In preparation for the fumigation test, groups of ducts were connected together by a manifold. As shown in figure 32, the manifolds connected groups of 5, 5, and 7 ducts down each side of the building. Each manifold was provided with a fan powered by a 3-hp. motor. These gave an airflow rate of approximately 0.25 c.f.m./bu. A return duct was extended from each fan back into the building in the headspace. The original intention was to recirculate the fumigant, but, on further consideration, it was decided to introduce the gas into the ducts and force it up through the grain sorghum mass.

Gas sampling tubes were placed at 57 locations in the grain sorghum portion of the load, as indicated in figure 32, at the surface and 8 and 16 feet deep in the grain sorghum, and in the headspace.

The methyl bromide dosage rate was increased to 4½ lbs./1,000 cu. ft. in the test, most of which was released in the duct system and pushed up through the grain sorghum until a satisfactory concentration was recorded at the surface level. The blower was then stopped, and 100 pounds of an 80-20 mixture of methyl bromide and chloropicrin was released in the headspace as in test G-2. The gas released in the headspace was included in the 4½ pound dosage rate.

The grain sorghum was heavily infested with rice weevils, lesser grain borers, flat grain beetles, flour beetles, Angoumois grain moths, and Indian-meal moths. Before fumigation the average infestation of 18 samples drawn from different portions of the grain mass was 379 insects per 1,000 grams of grain, and after fumigation, in samplings from the same locations, no living insects were found; caged test insects implanted in the grain sorghum and in the overspace above the grain in 14 locations were all killed by the fumigant.8/

Test G-5 was conducted in a large quonset, 400 x 40 by 20 feet high. It had a volume of 251,300 cubic feet and contained 180,000 bushels of grain sorghum and wheat when fumigated. The building was divided by bulkheads into five compartments. Three compartments were filled with grain sorghum and two with wheat. The studies were confined to the grain sorghum.

The aeration system was a single expanded metal aeration duct down the center of the floor. One hundred feet in from each end a lateral duct led through the outside wall, to which was attached a fan (fig. 33). A return duct led from each fan to the headspace. Each fan was powered by a 3-hp. motor, and the airflow rate was approximately 0.025 c.f.m./bu.

Gas sampling tubes were placed at 45 locations in the building, all but one in the section filled with grain sorghum, as listed in table 27.

A dosage rate of 4 lbs./1,000 cu. ft. was applied. The gas in this test was recirculated through the grain sorghum for 31 minutes.

The concentrations of gas and the distribution patterns are given in tables 23 to 27.

In test G-1 (table 23), where no insects were involved, the gas concentrations recovered from a 3-pound dosage rate with grain sorghum appeared to be in the range that would produce mortality of stored-grain insects. Grain sorghum is well known to be more sorptive than wheat and to require higher dosage rates. The airflow rate of 0.05 c.f.m./bu. appeared to be adequate to distribute the fumigant.

8/ Unpublished data supplied by L. M. Redlinger, Stored-Product Insects Lab., Houston, Tex.

In tests G-2 and 3 (tables 24 and 25), with a 4-pound dosage rate applied by the forced distribution method, supplemented with gas released in the headspace, good concentrations were obtained, and the distribution was fairly good. All samples of test insects placed in the surface layer 6 inches deep in the grain sorghum were killed, and no live insects were found in grain sorghum samples from various locations in the load.

In test G-4 (table 26) where a 4½-pound dosage rate was used and the gas was also applied by the forced distribution method supplemented by gas released in the headspace, the concentrations were higher than previously, and the distribution was excellent. Only one sampling point was low, No. 48, which could have been due to local leakage or to an accumulation of dockage at this particular point. No live insects were found in grain sorghum samples drawn after the fumigation.

In test G-5 (table 27) where the gas was recirculated, a dosage rate of 4 pounds resulted in a high level of concentration and a good distribution pattern except for one corner. This could have been due to leakage, or to inadequate airflow in this particular portion. No live insects were found in grain sorghum samples drawn after the fumigation.

It was concluded from this series of tests that the airflow rates in the range of 0.025 to 0.25 c.f.m./bu. will result in as good distribution of methyl bromide gas in grain sorghum as in wheat, and that aeration systems can be adapted to either recirculation or forced distribution of the fumigant in grain sorghum. The only difference evident between grain sorghum and wheat was the need for a higher dosage rate in grain sorghum due to greater sorption.

Table 23.--Distribution of methyl bromide in a quonset of grain sorghum resulting from recirculation for 22 minutes at an airflow rate of 0.05 c.f.m./bu., with a dosage rate of 3 lbs./1,000 cu. ft. and disappearance of gas resulting from forced aeration for 1 hour, test G-1

Sample location and number	Concentration per 1,000 cubic feet during fumigation					Concentration during aeration
	½ hour	2 hours	4 hours	8 hours	24 hours	
	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces
North side, west end						
1. Surface	4	3	2	0	0	0
2. 5 feet deep	30	22	17	10	5	0
3. Bottom	3	5	6	4	4	T
4. Surface	20	7	3	T	T	0
5. 5 feet deep	28	18	12	3	2	0
6. Bottom	20	15	12	6	7	0
North side, east end						
7. Surface	31	12	6	T	2	0
8. 5 feet deep	5	8	3	0	2	0
9. Bottom	10	12	6	4	4	T
10. Surface	19	8	2	0	0	0
11. 5 feet deep	0	14	9	6	4	0
12. Bottom	25	5	0	2	2	0
Center line, west end						
13. Surface	7	10	0	T	0	0
14. 5 feet deep	36	14	3	2	1	0
15. Bottom	30	6	0	0	T	0
Center						
16. Surface	17	8	1	0	0	0
17. 5 feet deep	14	12	4	2	1	0
18. 10 feet deep	14	11	6	3	4	0
19. Bottom	28	3	3	T	2	0
Center line, east end						
20. Surface	6	0	0	0	T	0
21. 5 feet deep	11	4	3	1	2	0
22. 10 feet deep	9	2	2	2	2	0
23. Bottom	6	7	6	6	6	T
Headspace						
24. West end	18	6	3	3	3	0
25. East end	11	3	1	2	2	0
South side, west end						
26. Surface	18	0	1	2	0	0
27. 5 feet deep	6	12	10	5	2	0
28. Bottom	25	14	10	8	4	T
South side, center						
29. Surface	26	6	4	3	1	T
30. 5 feet deep	22	18	14	7	3	0
31. Bottom	10	10	10	6	5	T
South side, east end						
32. Surface	22	9	6	3	5	0
33. 5 feet deep	17	20	14	5	4	0
34. Bottom	2	8	7	4	4	T
South wall						
35. Center	26	23	18	10	5	0

Table 24.--Distribution of methyl bromide and mortality of test insects in a quonset of grain sorghum resulting from forced distribution by operating the aeration fan reversed in position for 25 minutes at an airflow rate of 0.06 c.f.m./bu., and a dosage rate of 4 lbs./1,000 cu. ft., plus the release of 50 pounds of fumigant in the headspace, and disappearance of gas resulting from forced aeration for 1 hour, test G-2

Sample location and number	Concentration per 1,00 cu. ft. during fumigation					Concentration during aeration	Test insects 1/	
	½ hour	2 hours	4 hours	8 hours	24 hours		Size of sample	Mortality
	Ounces	Ounces	Ounces	Ounces	Ounces	Ounces	Number	Percent
West side, south end								
1. Surface	27	8	2	0	0	0	99	100
2. 9 feet deep	8	9	T	T	0	0		
3. Bottom	26	13	7	7	5	0		
West side, center								
4. Surface	35	10	2	2	0	0	35	100
5. 9 feet deep	30	16	12	7	5	0		
6. Bottom	27	12	8	6	4	0		
West side, north end								
7. Surface	14	10	5	T	0	0	19	100
8. 9 feet deep	28	7	4	2	1	0		
9. Bottom	8	4	2	2	3	0		
Center line, end to end								
10. Surface	22	7	0	0	0	0	62	100
11. 9 feet deep	25	1	0	0	0	0		
12. Bottom	24	3	1	7	2	1		
13. Surface	26	9	1	T	0	0	113	100
14. 9 feet deep	10	9	7	7	4	T		
15. Bottom	24	12	10	10	6	1		
16. Surface	24	10	0	T	0	0	70	100
17. 9 feet deep	10	8	5	6	4	T		
18. Bottom	22	17	13	8	6	2		
19. Surface	26	10	3	2	0	0	141	100
20. 9 feet deep	14	6	1	5	3	T		
21. Bottom	36	12	10	12	3	2		
22. Surface	42	20	3	2	0	0	76	100
23. 9 feet deep	16	11	6	8	6	T		
24. Bottom	41	22	10	9	10	1		
25. Surface	37	22	5	6	3	0	30	100
26. 9 feet deep	23	22	16	10	5	0		
27. Bottom	26	24	18	15	8	2		
East side, south end								
28. Surface	10	17	7	2	0	0	141	100
29. 9 feet deep	19	24	18	10	5	0		
30. Bottom	26	25	24	18	14	2		
31. Surface	35	15	11	5	0	0	72	100
32. 9 feet deep	19	12	14	8	8	1		
33. Bottom	20	14	17	12	6	2		
34. Surface	40	22	15	5	2	0	45	100
35. 9 feet deep	22	15	18	10	6	1		
36. Bottom	20	13	13	7	7	1		
37. Surface	32	29	14	0	0	0	88	100
38. 9 feet deep	38	25	8	T	0	0		
39. Bottom	18	12	12	5	6	0		
Headspace								
40. South end	16	2	2	0	0	0	63	100
41. Center	40	8	4	0	0	0	91	100
42. North end	40	19	4	2	0	0	38	100

1/ Insect samples used, also natural infestation found in grain.

Table 25.--Distribution of methyl bromide and mortality of test insects in a quonset of grain sorghum resulting from forced distribution by operating the aeration fan reversed in position for 25 minutes at an airflow rate of 0.06 c.f.m./bu., and a dosage rate of 4 lbs./1,000 cu. ft., plus the release of 50 pounds of fumigant in the headspace, test G-3

Sample location and number	Concentration per 1,000 cu. ft. after					Test insects	
	½ hour	2 hours	4 hours	8 hours	24 hours	Size of sample	Mortality
	Ounces	Ounces	Ounces	Ounces	Ounces	Number	Percent
West side, south end							
1. Surface	25	8	4	2	0	180	100
2. 9 feet deep	32	5	3	0	T		
3. Bottom	26	13	9	10	7		
West side, center							
4. Surface	20	15	4	2	0	185	100
5. 9 feet deep	18	9	4	2	T		
6. Bottom	18	10	9	8	5		
West side, north end							
7. Surface	38	12	4	2	0	160	100
8. 9 feet deep	44	14	3	1	0		
9. Bottom	11	2	1	2	3		
Center line, end to end							
10. Surface	12	9	4	0	0	119	100
11. 9 feet deep	32	16	22	13	6		
12. Bottom	200+	100+	96	26	8		
13. Surface	24	14	8	2	0	80	100
14. 9 feet deep	27	18	14	10	4		
15. Bottom	16	13	10	10	6		
16. Surface	22	15	8	3	0	105	100
17. 9 feet deep	30	6	4	1	0		
18. Bottom	16	20	24	23	8		
19. Surface	32	14	8	4	0	107	100
20. 9 feet deep	27	16	10	9	3		
21. Bottom	29	24	26	32	11		
22. Surface	26	20	8	9	0	165	100
23. 9 feet deep	42	17	7	8	1		
24. Bottom	28	19	22	20	10		
25. Surface	88	30	10	6	1	100	100
26. 9 feet deep	132	72	40	0	8		
27. Bottom	16	4	3	1	0		
East side, south end							
28. Surface	30	8	6	0	0	140	100
29. 9 feet deep	41	28	18	10	4		
30. Bottom	78	50	46	35	12		
31. Surface	47	11	8	4	0	171	100
32. 9 feet deep	10	6	9	7	0		
33. Bottom	8	12	15	10	4		
East side, north end							
34. Surface	21	17	9	4	0	155	100
35. 9 feet deep	0	0	4	2	0		
36. Bottom	0	0	2	0	2		
37. Surface	11	18	8	3	0	160	100
38. 9 feet deep	0	0	0	6	0		
39. Bottom	4	8	6	9	2		
Headspace							
40. South end	17	4	0	0	0	111	100
41. Center	42	7	2	1	0	126	100
42. North end	42	16	5	3	0	121	100

Table 26.--Distribution of methyl bromide in a quonset of grain sorghum resulting from forced distribution by operating the aeration fans reversed in position for 22 minutes at an airflow rate of 0.25 c.f.m./bu., with a dosage rate of $4\frac{1}{2}$ lbs./1,000 cu. ft. including 100 pounds of fumigant released in the headspace, test G-4

Sample location and number	Concentration per 1,000 cu. ft. after				
	½ hour	2 hours	4 hours	8 hours	24 hours
	Ounces	Ounces	Ounces	Ounces	Ounces
South side, east to west					
1. Surface	30	47	30	14	4
2. 8 feet deep . . .	22	40	32	22	14
3. 16 feet deep . . .	32	53	30	16	9
4. Surface	35	50	32	21	7
5. 8 feet deep . . .	30	45	34	24	4
6. 16 feet deep . . .	22	82	94	15	0
7. Surface	28	46	32	19	3
8. 8 feet deep . . .	23	45	37	29	4
9. 16 feet deep . . .	21	42	35	19	6
10. Surface	20	42	20	15	5
11. 8 feet deep . . .	46	36	32	22	4
12. 16 feet deep . . .	52	80	120	120	7
13. Surface	56	36	20	14	5
14. 8 feet deep . . .	66	40	20	20	2
15. 16 feet deep . . .	48	38	30	18	8
16. Surface	50	42	22	14	8
17. 8 feet deep . . .	50	37	26	22	4
18. 16 feet deep . . .	32	33	24	20	5
19. Surface	38	33	18	16	8
20. 8 feet deep . . .	38	33	22	18	6
21. 16 feet deep . . .	44	34	24	20	9
Center line, east to west					
22. Surface	50	34	26	20	8
23. 8 feet deep . . .	54	36	30	19	10
24. 16 feet deep . . .	55	38	36	43	10
25. Surface	37	23	20	19	9
26. 8 feet deep . . .	54	38	30	23	10
27. 16 feet deep . . .	62	45	44	70	12

Table 26.--Continued

Sample location and number	Concentration per 1,000 cu. ft. after				
	½ hour	2 hours	4 hours	8 hours	24 hours
	Ounces	Ounces	Ounces	Ounces	Ounces
28. Surface	55	34	26	25	16
29. 8 feet deep . . .	57	42	29	24	10
30. 16 feet deep . . .	50	38	23	16	18
31. Surface	38	24	20	16	9
32. 8 feet deep . . .	42	34	44	22	12
33. 16 feet deep . . .	44	36	27	29	7
34. Surface	20	20	17	19	12
35. 8 feet deep . . .	38	28	23	21	16
36. 16 feet deep . . .	34	136	128	100+	30
North side, east to west					
37. Surface	50	40	27	18	6
38. 8 feet deep . . .	48	38	29	20	6
39. 16 feet deep . . .	40	36	27	16	4
40. Surface	35	32	23	16	3
41. 8 feet deep . . .	40	28	18	14	8
42. 16 feet deep . . .	55	48	34	18	9
43. Surface	42	48	24	18	8
44. 8 feet deep . . .	48	32	4	11	8
45. 16 feet deep . . .	60	32	14	15	9
46. Surface	26	28	22	4	10
47. 8 feet deep . . .	39	12	18	7	5
48. 16 feet deep . . .	0	0	5	7	4
49. Surface	34	20	16	11	5
50. 8 feet deep . . .	30	18	16	14	10
51. 16 feet deep . . .	160	200	160	100+	60
52. Surface	40	32	20	11	10
53. 8 feet deep . . .	26	44	15	4	10
54. 16 feet deep . . .	38	48	28	28	10
Headspace					
55. North side	48	40	26	10	10
56. Center	20	40	26	8	6
57. West end	30	28	17	8	10

Table 27.--Distribution of methyl bromide in a quonset of grain sorghum resulting from recirculation for 31 minutes at an airflow rate of 0.025 c.f.m./bu., with a dosage rate of 4 lbs./1,000 cu. ft., test G-5

Sample location and number	Concentration per 1,000 cu. ft. after				
	½ hour	2 hours	4 hours	8 hours	24 hours
	Ounces	Ounces	Ounces	Ounces	Ounces
North side, west to east					
1. Surface	4	4	4	4	2
2. Middle	3	3	3	3	1
3. Bottom	3	4	4	4	2
4. Surface	38	20	6	6	4
5. Middle	44	26	18	17	10
6. Bottom	100+	42	16	26	4
7. Surface	40	23	6	7	6
8. Middle	33	22	14	9	10
9. Bottom	36	25	20	15	7
10. Surface	12	10	6	6	10
11. Middle	41	20	16	12	7
12. Bottom	38	16	12	10	4
Center line, west to east					
13. Surface	23	12	4	3	3
14. Middle	24	14	9	6	3
15. Bottom	58	53	100+	98	4
16. Surface	50	30	16	8	6
17. Middle	56	38	36	28	16
18. Bottom	54	63	100	92	4
19. Surface	52	20	8	8	3
20. Middle	45	35	28	25	11
21. Bottom	44	34	28	25	6
22. Surface	35	22	16	10	7
23. Middle	45	32	26	22	14
24. Bottom	100+	100+	100+	100+	6
25. Surface	42	30	16	8	9
26. Middle	43	32	24	20	10
27. Bottom	100+	84	100+	78	5
28. Surface	18	14	12	8	6
29. Middle	22	40	15	14	12
30. Bottom	100+	100+	100+	28	8
South side, west to east					
31. Surface	27	14	8	8	6
32. Middle	45	34	30	26	14
33. Bottom	30	28	26	24	9
34. Surface	16	12	6	7	4
35. Middle	28	22	20	20	12
36. Bottom	24	25	24	22	12
37. Surface	18	13	6	8	7
38. Middle	39	25	22	22	14
39. Bottom	27	36	24	24	7
40. Surface	T	6	6	7	5
41. Middle	8	10	8	8	6
42. Bottom	5	8	6	9	4
Headspace					
43. West end	10	6	4	4	0
44. Center	10	6	3	4	0
45. East end, 6" in grain	25	17	16	12	10

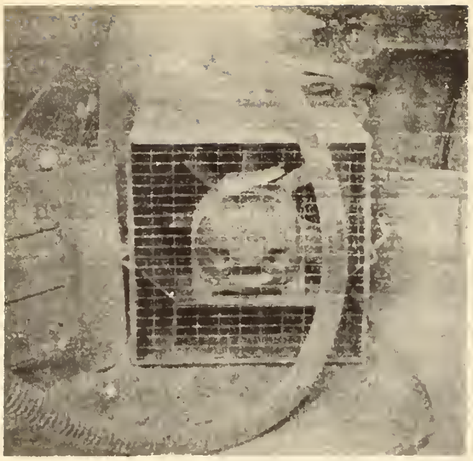

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Figure 30.--Fan of the aeration system in test G-1.

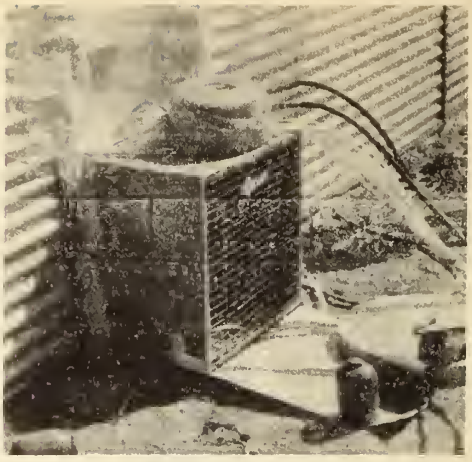

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Figure 31.--Fan of the aeration system in test G-2.

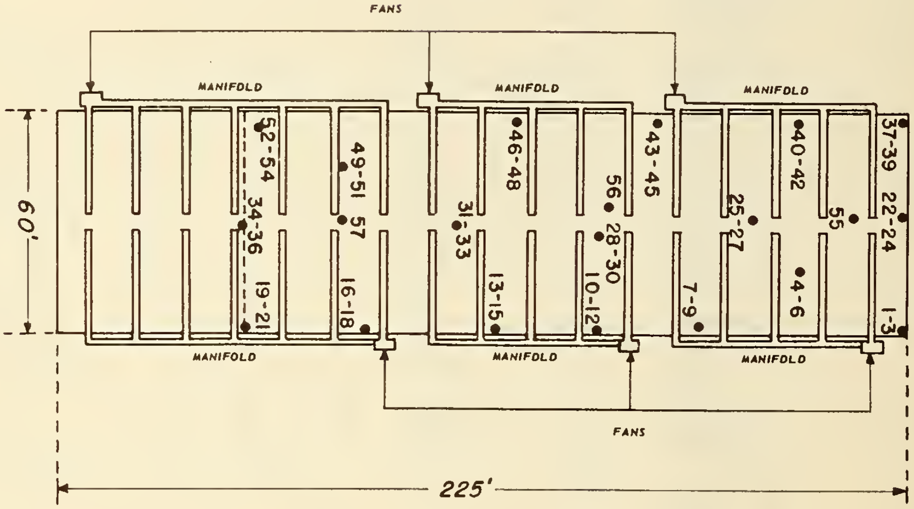

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Figure 32.--Diagram showing the aeration duct system in test G-4, and location of the gas sampling points.

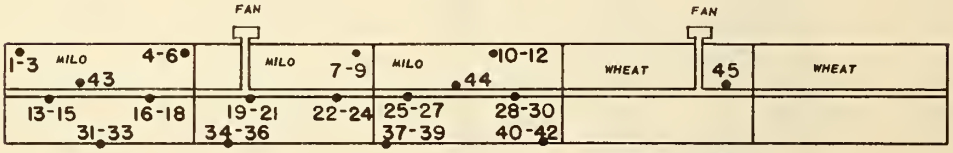

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Figure 33.--Diagram showing the aeration duct system in test G-5, and location of the gas sampling points.

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